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DEVELOPMENTS IN THE MANUFACTURE OF FINE WRITING PAPER

by

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CHAPTER I.

ORIGIN AND EARLY HISTORY OF PAPER.

It is impossible to state when the art of writing commenced. Before its use, songs, traditions, trees, heaps of stone, altars, and pillars were used to keep up recollection of past facts. Inscriptions on stones, wood and metals were used for public records, and leaves and barks of trees for private purposes. Job mentions the use of stone, which was also used by the early Danes. Later, bricks were also used. We are told the Ten Commandments were written on marble slabs. The first known Chinese writing was on stone. Lead replaced stone and bricks and was itself replaced by bronze. The speech of Claudius written on bronze plates is still preserved in the town hall of Lyons, France. Wood and ivory were next used and were superseded by the leaves of the palm olive, poplar, and other trees. Next the bark of the elder, elm and birch were used, also bamboo by the Chinese, and also the interior bark of the lime tree which resembled papyrus. The Chinese printed on linen and silk two or three centuries B.C., but linen moulded so they used skins later called parchment. Cloth

and skins were also used in Europe in the fourth century B.C., some handsome work in colored parchments with gold and silver letters being done.

The origin and early history of paper are involved in much obscurity. The word "paper" is derived from papyrus, the name of the writing material used by the Egyptians and manufactured from the papyrus plant. The plant is of the rush variety, with short leaves near the base and a tall triangular stalk with a large bush on top. It grows from ten to twenty feet in height. The pellicles of the stalk were separated by means of a pin or shell and spread out on a table sprinkled with Nile water until of the proper size and then washed with hot glue-like Nile water and a second layer laid crosswise, thus finishing a sheet which was pressed, hung to dry and afterwards smoothed and polished with a tooth or piece of ivory. About twenty of these sheets were made from one stalk, the nearer the pith, the better the sheet made. Although the exact time at which the manufacture of papyrus began is not known, there is a roll preserved in Paris which is computed to date at least 2000 B.C., and there is a record of papyrus being sold in Athens, in 407 B.C.

The Chinese appear to be the first people to manufacture paper from rags, but the exact date is uncertain, probably

about 200 B.C. At first they used raw cotton fibre but later on used old hempen clothes and fishing nets. Cotton paper did not become available to the rest of the world until 704 A.D., when the Arabs captured Samarkand and there learned how to make it. The art was introduced into Europe by the Moors who established works in Spain and made a fine quality, but with the passing of the Moorish kingdom the Christians took up the manufacture and the paper declined in quality. It was also early introduced into Italy and Greece, no doubt through the Arab occupation of Sicily.

As the manufacture pushed into other countries where cotton was not cultivated or used in great quantity, linen and other fibres were substituted. As early as 1189, paper was being made in France and it soon spread to other countries. In Germany, the industry was started in 1320, it being introduced from Italy. Another mill was built in 1390. Rag paper of the 14th century may generally be recognized by its firm texture and its stoutness and the size of its wire marks. The watermarks are usually simple in design and very strongly marked. In the course of the 15th century the texture gradually becomes finer and the watermarks more elaborate. The practice of inserting the full name of the maker in the watermark came into fashion in the 16th century.

There is evidence that paper was in common use in England at the beginning of the 14th century. The oldest

known MS. in England on cotton paper is dated 1049. There is a linen paper MS. dated 1320 which seems to show cotton to be the first made though this has been a disputed point. There is a linen paper in Spain dated 1178 which is the oldest known specimen of line paper. The first known paper maker in England was John Tate, who erected a mill in Hertford in 1498. A German named Spielman erected the second mill at Dartford, in 1588, and was made a knight by Queen Elizabeth. But the comparatively cheap rates at which paper was sold in the inland towns in the 15th century as well as those near the coast seems to afford ground for assuming there were mills before that of Tate. The Alton mill, sometimes called the home of hand made paper, was started about 1700 at Alton Hauts, a small mill town. The good quality of its product won the sovereign's esteem and it became the royal mill of England. It to-day supplies the government with stationery and shows no signs of being driven out of business.by machine made paper. In 1760, James Whatman of Maidstone is mentioned as having attained to great perfection in the manufacture of paper. This mill is at present the largest vat mill in operation, containing about twenty vats.

The British Patent Records record a patent of 1675, entitled "The Art and skill of making all sorts of white

paper for the use of writing and printing, being a new manufacture and never practised in any way in any of our kingdoms and dominions." But no specification of the patent is given, so the exact process cannot be stated. In 1682, a patent was taken out on a new engine for pulping various fibres and in the following years a number of patents on pulping engines were issued but no specifications are published. In 1750, the Hollander was invented. This invention is the foundation upon which the common form of beater now in use is based. The invention was made in Holland so naturally the power first used was windmills. In 1759, it was introduced into England and a little later in America. The early English pulping engines all worked on the crushing or hammering principle. The Hollander differed in that its process was a grinding one. Plate I, shows the essential details of a modern Hollander, which in principle is the same as the original invention. Fig. 1 is a plan, A being the tub wall now made either of wood, copper-lined for beaters, or of cast iron for washers. B is the beating roll mounted on the shaft C, of which the bearings are DD. The bearing on the roll side is adjustable vertically by means of the hand-wheel E. F, is a midfeather to make the passage for the pulp of equal width throughout. Figure 2, is an elevation through the section

MN of Fig.1,"a" being the roll, b, the steel bed-plate upon which the roll grinds and c the back-fall, a rise and sudden fall in the floor to produce momentum for the revolution of the pulp. The arrows show the direction of flow of the pulp. Fig. 3, is a section of the roll showing the steel knives and Fig. 4, is a plan of the bed-plate, showing the angularity of the knives, the purpose of which is to produce a shearing action thereby reducing the amount of power necessary for beating and also insuring the fibres being cut and not rolled in balls. These beaters are now made in capacities from 500 to 2500 lbs.

The first paper mill in America was built in 1690, by Wm. Rittenhouse. The location was a few miles from Philadelphia. Wealthy Philadelphians furnished most of the capital but by 1705, Rittenhouse was the sole owner. The second mill was built in 1710, by a relative of Rittenhouse. There were quite a number of mills built near Philadelphia. One, at Ivy Mills, was built in 1732, originally to make fullers' press boards but later it made paper for Franklin's newspaper and also the paper for the Continental money and at the same time commenced making fine writings. Franklin is credited with the starting of as many as eighteen mills near Philadelphia. In 1770, there were forty mills in America. The first mill in New England was built at Milton, Massachu-

setts, by Daniel Henchman, in 1730. In 1799, Zenas Crane set out to look for a sight for a mill and settled upon Dalton, Mass., situated on the Housatonic River, the main reason being the abundance and quality of the water supply. He built a one vat mill in 1801. A day's work was twenty posts, a post being 125 sheets. Foolscap, folio, book and news were made. His help consisted of an engineer at $3.00 and a vatman and a coucher at $3.50 a week without board; two girls and a man at 75¢ a week and a lay boy at 60¢, all being boarded. A few years later Crane received $9.00 a week as superintendent and manager.

CHAPTER II.

EARLY METHODS OF MANUFACTURING AND FIRST MACHINES.

Up to the beginning of the 19th century the making of paper was a hand process, and necessarily slow as was seen in the capacity of Zenas Crane's mill.

Before 1787 the color of the rags determined largely the color of the product, though it was in 1746 that the art of coloring rag stock was accidentally discovered by the wife of an English paper maker dropping her blueing bag in a vat of white pulp. The rags after being sorted for color, were cut up, sprinkled with water and made into a heap, thus causing the rags to heat and ferment. The mass was turned occasionally to prevent over heating. This primitive process oxidised and rendered soluble the waxy, gummy, and resinous constituents associated with the fibre. This "retting" or rotting process took weeks and sometimes months for its completion and the stock was then scalded in an open pan, at first with a live fire directly underneath. Sometimes quicklime or ashes were added to remove the grease. Later, alkalis were used and various forms of kiers and boilers took the place of the open pan, steam under a pressure varying up to eighty pounds being used to supply

the necessary heat. The boiled rags were washed, spread out on the grass in the sun and occasionally turned and sprinkled with water. The process was long and slow and the final result very uncertain. Sun or grass bleaching had one redeeming feature, however, - it did not injure the fibre.

Scheele discovered chlorine in 1744 and it was first used for bleaching in 1787. Bleaching powder was not used until 1799. The gas was used by placing the washed rags or "half stuff" in stone chambers and generating the chlorine in stone retorts. This process, though effective, was very cumbersome and by no means pleasant in consequence of the escape of chlorine gas into the surrounding atmosphere. In spite of the difficulties of this process, it died hard, being used many years after bleaching powder was introduced, the reasons for this no doubt being a reluctance to give up the use of the stone vaults and appliances which it had cost considerable to install, and the fact that chlorine gas was very rapid and sure in its action and had the advantage over bleaching powder that it did not add lime salts to the fibre. In time, bleaching powder became, and is now, universally used. As stated before, the Hollander is the form of beater most generally used.

As made to-day, the pulp when beat, is run into chests

from which it is drawn or pumped into the vats, being strained during the passage to the vats. The paper is made on a mould—a frame covered with very fine wire cloth and surrounded by a removable frame of wood called the "deckle," its object being to keep the pulp from running off the sides. The vatman dips the mould into the vat, filling it with pulp to the top of the deckle, then runs the stuff evenly over the mould throwing back any excesses and then he gives the mould a shake both longwise and crosswise, thus driving the water through the wire and interlacing the fibres into a sheet of paper. The coucher now takes the mould, removes the deckle and, after draining a short time, places the mould face down on a piece of felt. The paper adheres to the felt and is covered with another piece and so on, until a post has been made. The post is taken to a press where some of the water is pressed out. The sheets are then removed from the felt, layed upon each other, and again pressed, after which they are hung to dry in spurs of from three to five sheets. When dry, the paper is passed through the size box and rollers and again dried at about 80 degrees Fahrenheit. It is readily seen that this was and is a very slow process, and that it would be utterly impossible to supply the present demand by the hand process.

Louis Roberts, an employee of Messrs. Didot of the celebrated Essonnes Mills, near Paris, first conceived the idea of making paper by means of an endless wire machine. In 1799, he erected a rude machine and was granted a premium of 8000 francs and a fifteen year patent by the French government. Leger Didot, Roberts' employer, bought the patent and with John Gamble took it to England. Gamble's British Patent No. 2487, of April 20th, 1801, describes in detail the first attempt at a machine. It is for making single sheets without seaming from one to twelve feet and upwards wide and from one to forty-five feet and upwards in length. Plate II, taken from the Patent Office drawings, shows the principle of the machine. Fig. 1, is a plan of the machine. A, is a vat to contain the pulp. B, is an endless sheet of copper wire-cloth which runs over two rolls, C and D, and between two rolls at E. There are copper clasps at equal distances along the edge of the wire which edges are also bordered by eel skin—this corresponding to the deckle of to-day. The clasps slide on copper rulers extending along the sides from C to E, to guide and support the wire. F, is a paddle wheel dipping into the pulp and supplying a steady flow upon the copper wire. The rear end of the wire is given a shake by means of the balancer, G, which engages

with an octagon, H, on the shaft, S. The handle, P, at every turn, gives the balancer, and therefore the wire and pulp on it, twelve jerks. The arrangement of the gears is easily seen from the figure. The method of taking off the paper is by use of the roller, R, which is kept in contact with wire by its own weight. The roll is kept wet, so the paper adheres to it and reels itself on the roll which, when full, is replaced by another one and the process continued. Fig. 2, is an elevation of machine; aa, are felt-covered rollers to which pressure is applied by the handwheel, b. There is a slant of two centimeters from aa to c. It is seen that this machine is quite similar to the modern cylinder wet machine. The first machine was built in Hall's machine shop at Dartford, Kent. Hall's assistant was Bryan Donkin, who developed the patents of Gamble which were bought by the Froudrinier Bros.,- stationers in London. Donkin had the first successful machine going in 1803. Henry and Sealy Froudrinier spent a large amount of money in perfecting the machine and, while it never brought them any returns in a financial way, it connected their name to the machine forever. Henry Froudrinier took out a patent in 1806 for making paper of an indefinite length, both laid and wove, by use of separate moulds which

were fastened together on a platform provided with rollers and hung so as to be free to move sidewise. A cylinder covered with an endless felt bore down on one end of the platform, the stuff flowing on at the other end. The felt took the paper off as the moulds were moved along, the moulds being taken off and added at the proper ends. The paper was passed through two sets of press rolls and reeled up or cut off in any convenient way. In 1812, Didot took out a patent for certain improvements on Gamble's and Froudrinier's machine. It was for making single sheets and the moulds were not removed but were washed on the under side while passing back. A vacuum pump was used to remove water. The paper was removed from the mould when the latter was upside down and passing back on the under side. The wet felt passed over the couching roll as was the case in most all of these first machines. In 1817, Didot's Patent for improvements is accompanied by complete drawings. It would seem that Didot was the owner of all of Gamble's and Froudrinier's rights and patents. This machine was for making both sheets by use of moulds and an endless web by use of wire. The deckles used on the wire machine were also applied to the mould part of the machine. The same couching roll was used for both moulds and wire. Plate III, gives

an idea of the construction of the machine. A, is the stuff chest; B, is the mould part of the machine which can be removed. C, is the endless wire for making continuous web paper. D, is the couch roll covered with the felt F, which carries the paper back over the machine to the press P, after which it is reeled off. D drops to D', when using the endless wire part. Bryan Donkin was the great mechanical engineer who really made these improvements and many more. His machines were wonderfully fine pieces of workmanship. In fact, he so perfected the machine by 1832 that no essential changes have been made up to the present time.

An entirely different form of machine was invented about 1805. Joseph Bramah in that year took out a patent for a machine consisting of a cylinder covered with wire upon which the pulp was lead and the sheet taken off by a couch roll, passed through presses, between heated calender rolls, and cut or reeled in rolls, However, John Dickinson is usually credited with the invention of the cylinder machine which he patented in 1809. Plate IV, Fig. 1, shows the arrangement of his machine. A, is a large chest into which the stuff is emptied from the beater. B, is a small chest eighteen inches in diameter and height in which the pulp is

kept at a constant height by a float valve. From B, the pulp flows through the pipe C, which contains a valve into the pipe D, in which a steady stream of water is flowing towards E, in which the pulp and water become thoroughly mixed. From E, the pulp flows into the box F, which partly surrounds the perforated, wire-covered, brass cylinder, G. Inside of G is a trough, HH, whose edges fit closely against the interior of the cylinder. One end of this trough is connected by the pipe I, to a pump working in a cistern of water, thereby removing the pressure on the inside of the cylinder which will allow the atmospheric pressure to force the water out of the pulp through the cylinder surface into the trough and out the pipe I. The cylinder revolves as shown, the pulp adhering to the wire surface, thus forming a sheet of paper which is removed by the smooth roll, R, revolving as shown by the arrow. The web then passes between R and M, M having a perforated surface, and from M cut in sheets or reeled off. In 1811, Dickinson substituted a felt-covered couching roll and two presses for the rolls R and M. The advantage claimed for the use of this machine was. the use of the vacuum pump, thereby taking out the water faster than with the Froudrinier machine and therefore increasing the speed of production. There is no sidewise movement given to the fibres, so the disadvantage of the

machine was that the fibres were not interlaced enough to make paper anywhere equal in strength both ways. In 1826, M. Canson applied suction to the Froudrinier machine, thus depriving the cylinder machine of its advantage. Cylinder machines are used to-day principally for making cheap card-board, box board and manila paper and also for wet machines in pulp mills. In 1817, Dickinson patented a method of tub sizing in the endless web by first drying the paper on steam cylinders and passing it between two rolls, spraying the size on one roll. The speed used was six to fifteen feet per minute, the latter being a maximum which, if exceeded, would cause the surface to cockle.

While Willis is credited with the invention of the dandy roll, in 1830, J. & C. Phipps, in 1825, patented a roll from five to twelve inches in diameter to be placed on a Froudrinier machine to give the sheet a laid surface, which is really a dandy roll. There were, about 1830, quite a number of patents taken out on "strainers" or "knotters," now called screens. J. Dickinson used a revolving cylinder with longitudinal apertures about 1/115 of an inch wide. Henry Brewer, in 1832, patented a sieve which was given a quick up and down movement by means of a crank. J. Ames patented the substitution of plates of brass with cut slits

for bars and rods, as the latter gave trouble by working loose. In 1832, Sellers, of Philadelphia, patented a strainer, the principle of which is explained by Fig. 2, Plate IV. The roll was put in a vat of pulp and revolved as the arrow indicates, the surface A, being slit and B, being plane. Any number of surfaces could be used. The strained pulp was lead off to the machine through a hollow axle. In 1833, T. Wrigley, of England, patented a pulp strainer consisting of a piston working in a perforated cylinder, the whole being placed in a pulp vat. In 1835, Dickinson patented the use of a series of magnets to extricate particles of iron and steel and also an arrangement whereby he claimed to make the fibres deposit themselves both transverse and parallel to the movement of the cylinder. In 1854, Moses Poole patented a method of giving the cylinder of the cylinder machine a horizontal vibration, or giving the pulp currents at right angles to the direction of travel by means of screws. In 1831, paper was made on the Froudrinier machine at the rate of twenty-two feet per minute whereas Dickinson's machine made forty-eight feet.

Though the originator of the paper machine was a Frenchman, a machine was not built in France until 1815. It proved a failure and in 1823, one of Bryan Donkin's English machines was the only one in operation. The first

machine was operated in Germany in 1818. The first machine in America was owned by Thomas Gilpin in his mill on Brandywine Creek in 1816. It was a Dickinson cylinder machine, the cylinder being imported from England. Its dimensions were, diameter, two feet and length, three feet. The wet paper was wound on a roll 'till the proper number of layers, then cut and hung up to dry. A New Jersey Frenchman invented a new cylinder, very light and inexpensive, about the same time that John Ames, of Springfield, invented his machine. This was in 1822. Several suits arose from this coincidence. The Sellers Company were building cylinder machines before 1829, after the Ames model, but with some improvement by Sellers. The machine was much simpler than Gilpin's. In 1829, the cost of setting up and starting a small cylinder machine was about $600.00. In 1825, Ames' mill at Springfield was the largest in the United States, containing twelve engines. In 1829, there were sixty mills in Massachusetts, six having machines, but about 1830, there was a very rapid change to the use of machines. Phelps and Spafford,of Windham, Conn., made the first Froudrinier machine, in 1830. It was complete, with steam dryers, and was a close copy of Bryan Donkin's machine. Soon afterwards, Howe & Goddard, of Worcester, Mass., began manufacturing them, but these were the only two firms so occupied

in 1850. The cylinder machine was in more general use and made by more firms. An idea of the rapid change and growth of the industry may be had from the fact that in 1844, there were six hundred mills in the United States and by 1847, only two mills were making paper by hand. Zenas Crane put in an Ames cylinder machine in 1831, adding steam dryers in 1834.

We have not attempted and do not mean to attempt to follow all the developments in the machinery for preparing pulp and making the sheet of paper. It would be impossible to do so, as all the improvements have not been patented, so we do not know their date or who to credit them to, and again, many of the patents are on devices and so-called "improvements" which are worthless and no longer in use. However, there are one or two phases of the process in which radical changes have been attempted or made. The most important of these changes was the invention of the Jordan Refining Engine, which was patented in this country in 1858. Figs. 3, 4 & 5, Plate IV, show the general construction of the first Jordan. Fig. 3, is a side elevation of the exterior of the machine, A, being the chest from which the pulp is fed in; P, being the pulley for driving the conical grinder, and W, being the handwheel by means of which

the grinder is forced closer to or withdrawn from the outside shell. Fig. 4, is a view of the grinder, showing the arrangement of the steel knives in three sections, farther apart at the small end than at the large, and all the knives having a slight taper from the horizontal, to give a shearing effect, the same as in the case of the beater bed-plate. Fig. 5, is an end view of grinder and knives in the outer shell. Marshall later added a brushing disk at the large end. Quite recently, Mr. Wagg, at present superintendent of the Fox River Paper Company, at Appleton, Wisconsin, patented a refining engine which is an improved Jordan. It has both beating and brushing bars on the same cone so that one handwheel adjusts both. These refining engines are great savers of time, the stuff being only partially beaten in the beaters and then run through the refining engine which prepares it for the machine. These engines, of course, run at quite a high speed—300 to 400 R.P.M.—and take a large amount of power. Another part of the process upon which improvements have been attempted, but without success, is the use of a roller suction box on the Froudrinier machine. The boxes in use have plane, stationary tops, about eight inches wide, made either of wood or brass and perforated with a large number of holes. The sliding of the fine wire

over these surfaces under pressure necessarily shortens very materially the life of the wires. Beginning about 1860, there have been a large number of patents issued both in this country and in England, for roller suction boxes, one being taken out in this country Dec. 23rd, 1902, but as far as known, there is not one in successful operation anywhere.

CHAPTER III.

MODERN PAPER MAKING.

Rags are to-day, as in the past, used for making all fine writing papers, but the process of preparation has been greatly improved. These rags are obtained from all over this country and a large quantity are also imported, largely from Germany and Japan. The rags come to the mill in pressed bales varying in weight from 500 to 1200 pounds. The first process is to thrash out the loose dirt. Plate V, shows the thrasher and the thrashed rags. The thrashing cylinder is still and the cast iron arms on it can be plainly seen. From the thrasher the rags are taken to the sorting room, Plate VI, where they are sorted according to grade of fibre and also to amount of dirt. All metal, such as buckles and buttons, is removed, also all rubber and rubber cloth, as rubber cannot be dissolved out and shows up as specks in the finished sheet. The rags, when sorted, are cut as shown in Plate VII. There are two cutters at right angles cutting the rags into pieces about two inches square. From the cutter the rags pass through three dusters, also seen in Plate VII, and thus practically all the loose dirt is removed.

The cut and dusted rags are next put in the "rotaries,"-large boilers set horizontally and fixed to rotate slowly. Plate VIII, shows two of these boilers. Each holds 10,000 lbs. of rags to a "bleach" and to each bleach from 600 to 1,000 lbs. of lime previously dissolved is added, also a small amount of caustic soda for the darker grade of rags. This mixture of rags and lime is boiled under about 40 lbs. steam pressure for twelve hours, by the end of which time, the coloring, resinous, and gummy constituents of the fibre are thoroughly loosened and in a form readily separated from the fibres. The cooked rags are emptied on the floor beneath the boilers and the dark, dirty solution allowed to drain off after which they are shoveled into the boxes seen in the picture and taken to the washers, Plate IX. These washers are Hollanders, previously described. Those in the picture are made of cast iron and of about 600 lbs. capacity. Fresh water is run in at one end and the dirty water taken out by means of wire-covered cylinders. It takes about five hours for washing, at the end of which time, the cylinders are raised, the water shut off, and the bleaching solution run in. This solution has been prepared in the basement by dissolving bleaching powder, $Ca(ClO)_2$. Most of this powder is imported from England. Some idea of the

amount used is obtained from the fact that 110,960,523 lbs., valued at $1,371,028.00 were imported in the year ending June 30th, 1901. The commonly accepted and probably true theory of hypochlorite bleaching is, that the destruction of the coloring matter is due primarily, not to the action of chlorine, but to that of oxygen which is set free in the decomposition of water brought about by the chlorine which unites with the hydrogen of the water to form hydrochloric acid. Bleaching, therefore, becomes a form of burning or wet combustion in which the coloring matters are oxidized by the liberated oxygen, the final products of the oxidation being carbonic acid and water, while the cellulose, being freed from the foreign matter with which it was first associated, appears in its natural, uncolored condition. Chlorine does not, as a rule, destroy mineral colors, or the blacks and greys produced by lampblack or deposited carbon, so these blacks and greys have to be sorted out in the rag room. Bleaching powder is valued by the amount of "available chlorine" present. Just enough solution is added to the washed rags to "bring them to color," after which the bleached "half-stuff," so called as it is about half beatmn by this time, is let down into the drainers, Plate X, which are brick vaults with porous bottoms to permit

the water to drain off. The bleaching process goes on to some extent in the drainers and if an excess of bleach were added a marked injury to the fibre would take place. When properly drained the half-stuff is taken out as seen in the picture. It is now practically pure cellulose ($C_6H_{10}O_5$), which is the basis of all paper no matter what form it be obtained in.

The half-stuff is now added to the beater seen in Plate XI. The capacity of these beaters is 1,000 lbs. The time taken for beating depends upon the grade of stuff used. For the best bond paper the stuff is in the beater twelve to fifteen hours. When first put in the beater the stuff is either washed to remove any traces of bleach or an antichlor is used. There are several of these in use, the chief ones being sodium thiosulphate ($Na_2S_2O_3 \cdot 5H_2O$), sodium sulphite (Na_2SO_3) and Horsford's Antichlor, calcium sulphite ($CaSO_3$). The working of $CaSO_3$ is seen from the reaction, $Ca(ClO)_2 + 2CaSO_3 = CaCl_2 + 2CaSO_4$, the products being calcium chloride and calcium sulphate. During the process of beating mineral fillers are often added. They are used for their beneficial effect upon the feel and finish of the paper. The materials commonly used are some of the better sorts of china clay or kaolin, ground talc and sulphate

of lime ($CaSO_4 \cdot 2H_2O$). From 30 to 80% of the filler is retained in the paper, the higher figure only under exceptional circumstances, however. Near the end of the beating process the size, alum and coloring matter are put in. The object of sizing is to fill up the pores and coat the fibres with some material which shall offer sufficient resistance to the passage of fluids to prevent the spreading of ink. In the days of hand-made paper practically the only material used for sizing was gelatine, called animal sizing or tub sizing. Illig invented resin sizing about 1800. The formation of resins is not fully understood but they are known to be immediately derived from the oxidation of essential oils which occur in the tree. Cross and Bevan say resin is a mixture of pinic and sylvic acids. Sizing has always been a troublesome point and even to-day many mills have have trouble in properly sizing their product. The present method of resin sizing is to dissolve the resin in a soda ash solution, forming a resinate of soda but leaving varying amounts of free resin. This resinate of soda is added to the pulp in the beater and an alum solution added. The authorities do not agree as to just what takes place. Dr. Würster and Dr. Carl Dreher claim that the alum precipitates free resin upon the fibres, while Dr. Burckhart and Griffin and Little think that resinate

of alumina is what is precipitated. From a study of both theories it would seem that this latter view is the correct one. Various other substances have been tried for sizing. Alum has been used alone but has absolutely no sizing properties. Animal size is made by boiling hides. Alum is added as a preservative. Animal sizing is the best sizing and is used in connection with resin size for all fine writing papers at the present time although there are several patented sizes on the market for which great things are claimed. The dyes ordinarily used for coloring are ultramarine, carmine, analine, chrome, yellow paste and pastes for Venetian red and black.

The stuff, when beaten, is let down into the stuff chest, Plate XII, of which there are two to each machine. From one chest the stuff passes through a refining engine and back into the other chest from which it is pumped onto the machine, the so-called Froudrinier part of which is seen in Plate XIII. Before passing onto the wire the stuff is passed under a strong electro-magnet which removes any iron it may contain. It then passes through a screen or knotter which removes all the lumps and knots of unground fibre. On Plate XIII, the straps seen passing over the three small wheels are the rubber "deckles." The small roll

near the center of the picture is the dandy roll and the two large rolls on the left are the couch rolls, the upper one being covered with felt. Plate XIV, shows the two felts and presses which receive the paper web from the couch roll and, after pressing it, pass it on to the steam dryers which are seen to the left of the picture. Plate XV, shows all the first set of dryers and the size tub where the animal size is applied, the size being kept at about 120 degrees F. Here is where the difference between machine and loft dried paper comes. In machine dried, the web, after passing through the size tub, passes through a second set of dryers, a calender of iron rolls, is reeled up and slit and re-reeled, as seen in Plate XVI; whereas with loft dried, the paper is cut in sheets after leaving the size tub. Plate XVII, shows the super-calenders for the machine dried paper, consisting of alternate iron and paper rolls. Plate XVIII, shows the cutters and in the center a girl counting the paper. Plate XIX, shows two loft dried machines, the one to the left being unloaded. The damp paper is hung in spurs of from ten to twenty sheets on pine poles, as seen in Plate XX. When hung, the steam is turned on and the temperature maintained at about 120 degrees F., until the paper is dry, when it is pulled down, as seen in Plate XXI, and afterwards "jogged" or evened up, as seen in Plate XXII.

Plate XXIII, shows the sheet calenders, the sheets being fed in by hand. Plate XXIV, shows the paper being sorted on the table at the left side, and a trimming knife is seen in the center. Plate XXV, shows the ruling machines, the self-feeder being clearly seen in the foreground. Plate XXVI, is a view of the packing room.

CHAPTER IV.

GROWTH AND PRESENT SIZE OF INDUSTRY.

The century just past has witnessed a marvelous growth in the paper industry. Many causes have contributed to this wonderful development, the greatest of these being the newspaper. While we are not dealing with this side of the industry, it may be interesting to take up the growth as a whole as well as the fine writing side. In 1776, there were thirty-seven publications in the colonies; in 1900, the number had increased to twenty thousand eight hundred and six regular daily, weekly and monthly publications, to say nothing of the myriad of intermittent publications. The supply of rags early became insufficient to keep up with this phenomenal growth, even though large amounts were imported, beginning about 1810; so many different substances were tried and used for making print and other cheap papers. About 1800, M. Kpops patented a process for removing the ink from waste papers and waste papers are used largely to-day in the manufacture of book and medium grade papers. The old papers are boiled in an open, cylindrical tank, with a soda ash solution. The tank has a

false bottom which when raised drains the dirty liquid off, after which the papers are washed, bleached and beaten the same as rags. Koops also made the first paper from straw which has since become a raw material of considerable value. However, wood pulp is the most important of the comparatively new fibres. The process of making ground wood was invented in Germany in 1844 and soon after introduced into this country. The wood is simply ground to a pulp by large grindstones. Very few of the impurities become removed and the fibre has very little strength when used alone, which is seldom done. The soda process of treating wood was invented in England, in 1853. Soft woods, such as poplar, are used and the pulp is soft and has very little strength. The sulphite process was invented in this country in 1867 and is now largely used. Spruce is most largely used though several other trees are used to some extent. Even to-day the best grades of sulphite pulp are imported from Germany. The first wood pulp in the United States sold for 8¢ a pound, while to-day it sells for less than 1¢. England could not use wood as a fibre so the Spanish esparto grass was introduced when rags could not supply the demand for paper and this grass is now largely used.

By looking at Tables I, II, and III, Plates XXVII and

XXVIII, the rapid growth in the number of mills and their production can be seen for the United States, Massachusetts and Wisconsin. In Table I, the seven hundred and sixty-three establishments in 1900, represent over one thousand mills, employing over fifty-two thousand people. It is noticeable that less rags were used in 1900 than 1890, even though more fine writings were produced. Wood pulp and waste papers were used as substitutes. While the decrease in the cost of rags used from 1890 to 1900 was 11%, the decrease in the value of the product was 24%, showing the fierce competition in the paper line as well as in all others during the last decade. Massachusetts has been the center of the fine writing industry from early times as can be seen by Table II and also by Plate XXIX, which shows the distribution of the fine writing mills throughout the United States. Of the seventy-seven mills shown, forty are in Massachusetts, seventeen of these being in the city of Holyoke, which is the greatest paper center in the world, turning out each working day some two hundred tons of paper, nearly one-half of which is loft dried writing. The value of this enormous product for 1900 was $8,109,485.00. As seen by Table III, Wisconsin has not been manufacturing fine writing paper many years but its present output is quite large.

In total output of paper it ranks third, New York being first, Maine second, and Massachusetts fourth.

To produce this enormous amount of paper some wonderful machines have been built and are in operation. Print machines are made as wide as one hundred and sixty-five inches and the paper turned out at as high a rate as five hundred feet per minute. The Great Northern Paper Company, of Millinocket, Maine, puts out two hundred and fifty tons of print every twenty-four hours. Fine writings cannot be made at this speed, fifty to one hundred feet per minute being the speed for loft dried, while machine dried can be made up to two hundred feet per minute. There is one hand-made paper mill in this country, at Adams, Mass. Its present capacity is ten to fifteen reams per day, the paper being used for drawing, water-color painting, correspondence and special book editions. In the Appendix will be found a number of samples illustrating the variety of grades and colors made by a modern fine writing mill. The Hickory and No. 1 Fines, are loft dried papers while the remainder are machine dried. These papers are made by the Shattuck & Babcock Company Div., of the American Writing Paper Co., at De Pere, Wis. Plates V to XXVI are views of the interior of this mill.

In closing, it is desired to call attention to the lack of a technical course in paper-making in this country. Germany is far ahead of both England and the United States in this respect. To-day, there are in German factories 4500 trained chemists, besides more than 5000 assistants, whose brains are constantly at work upon the problems of improving processes, lessening the cost of production, etc. England is waking up to the fact that Germany has an advantage. As Dr. Dewar put it, "It was in the abundance of men of ordinary plodding ability, thoroughly trained and intellectually directed, that Germany at present had so commanding an advantage. It was the failure of our schools to turn out, and of our manufacturers to demand, men of this kind, which explained our loss of some valuable industries and our precarious hold on others." He laid this all to the lack of education, saying further, "Although we originated the whole thing upon which the chemical industries of Germany are built up, we have not the diffused education without which the ideas of men of genius could not fructify." In consequence of this and other stirrings up, courses in the chemical industries have been instituted in England. One of the late Dean J. B. Johnson's ideas of enlargement for the Engineering School of the University of Wisconsin,

was the starting of chemical engineering courses as applied to the chemical industries, - brewing, beet sugar manufacture, paper manufacture, etc., and it is to be sincerely hoped that these ideas will be enlarged and carried out in the near future.

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APPENDIX

PLATE I.

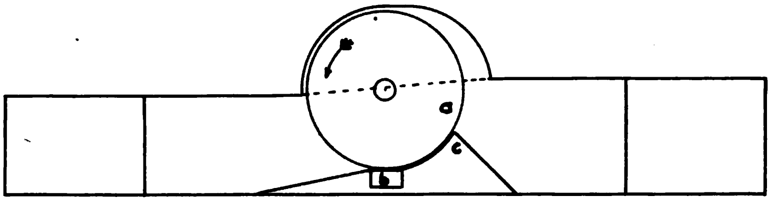


FIG. 2.

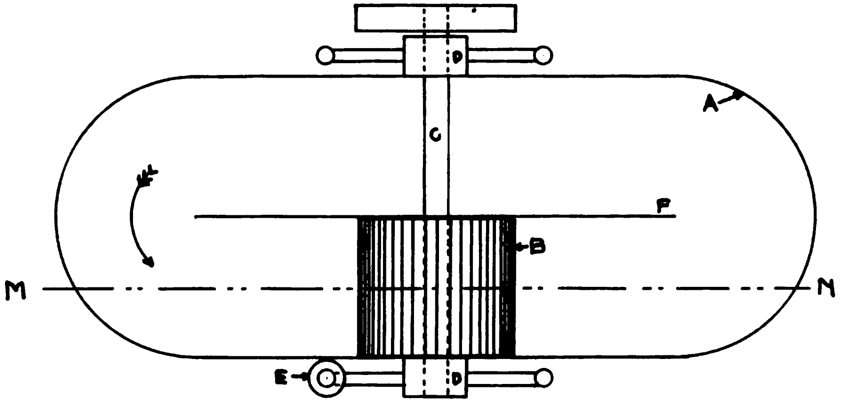


FIG. 1.

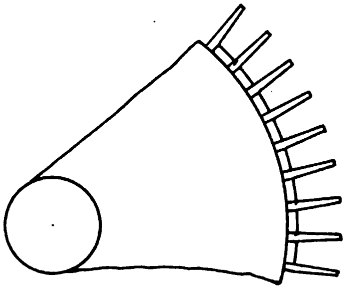


FIG. 3.

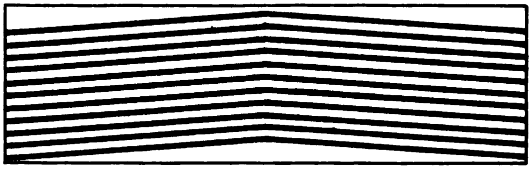


FIG. 4.

PLATE II.

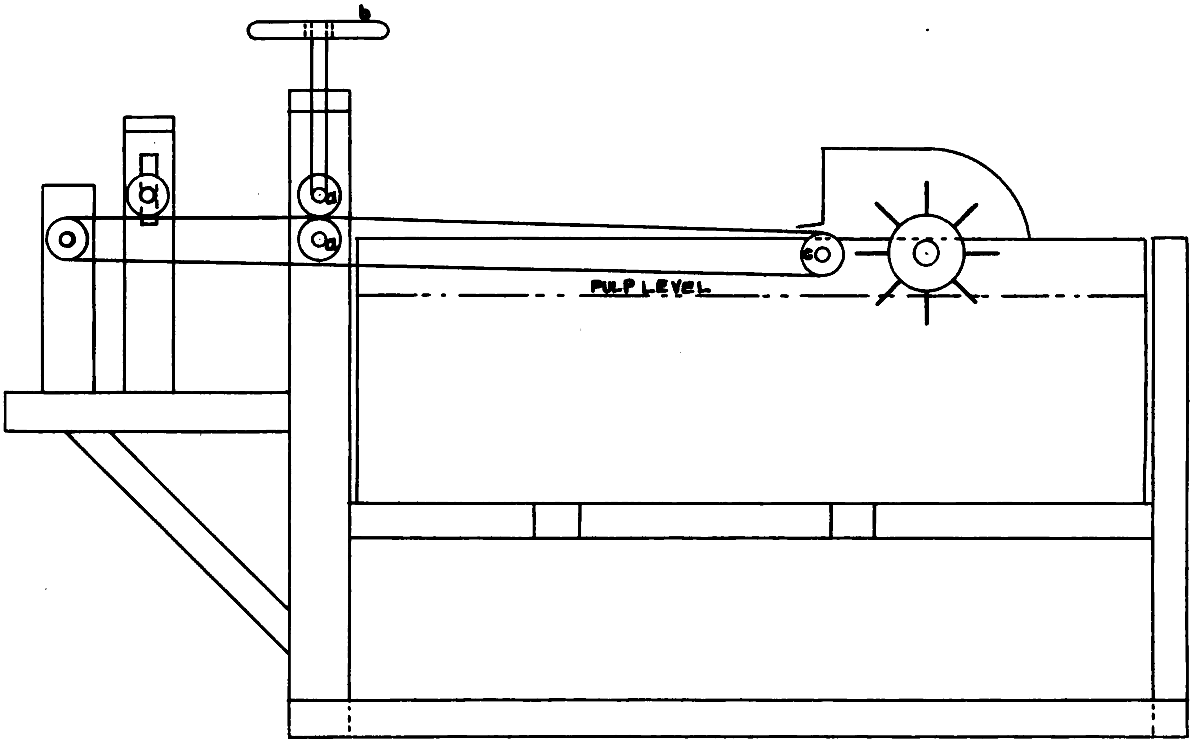


FIG. 2.

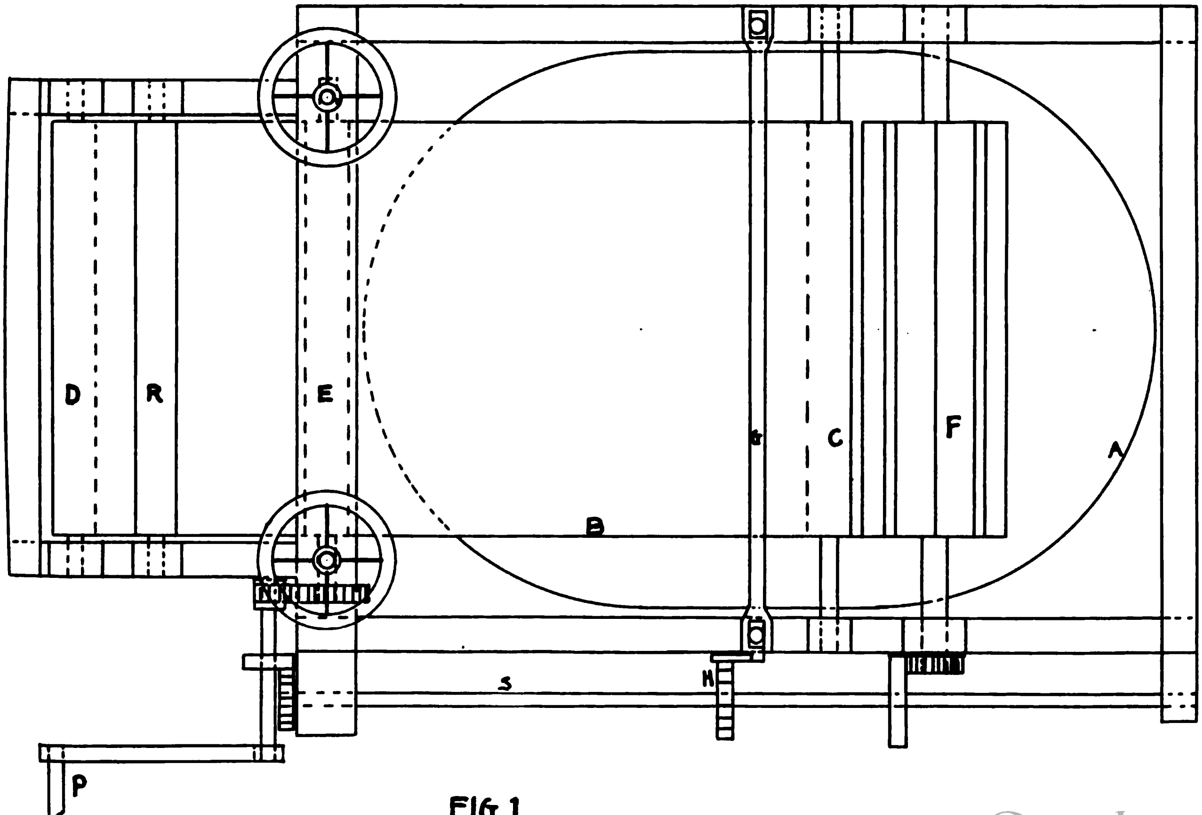


FIG. 1.

PLATE III.

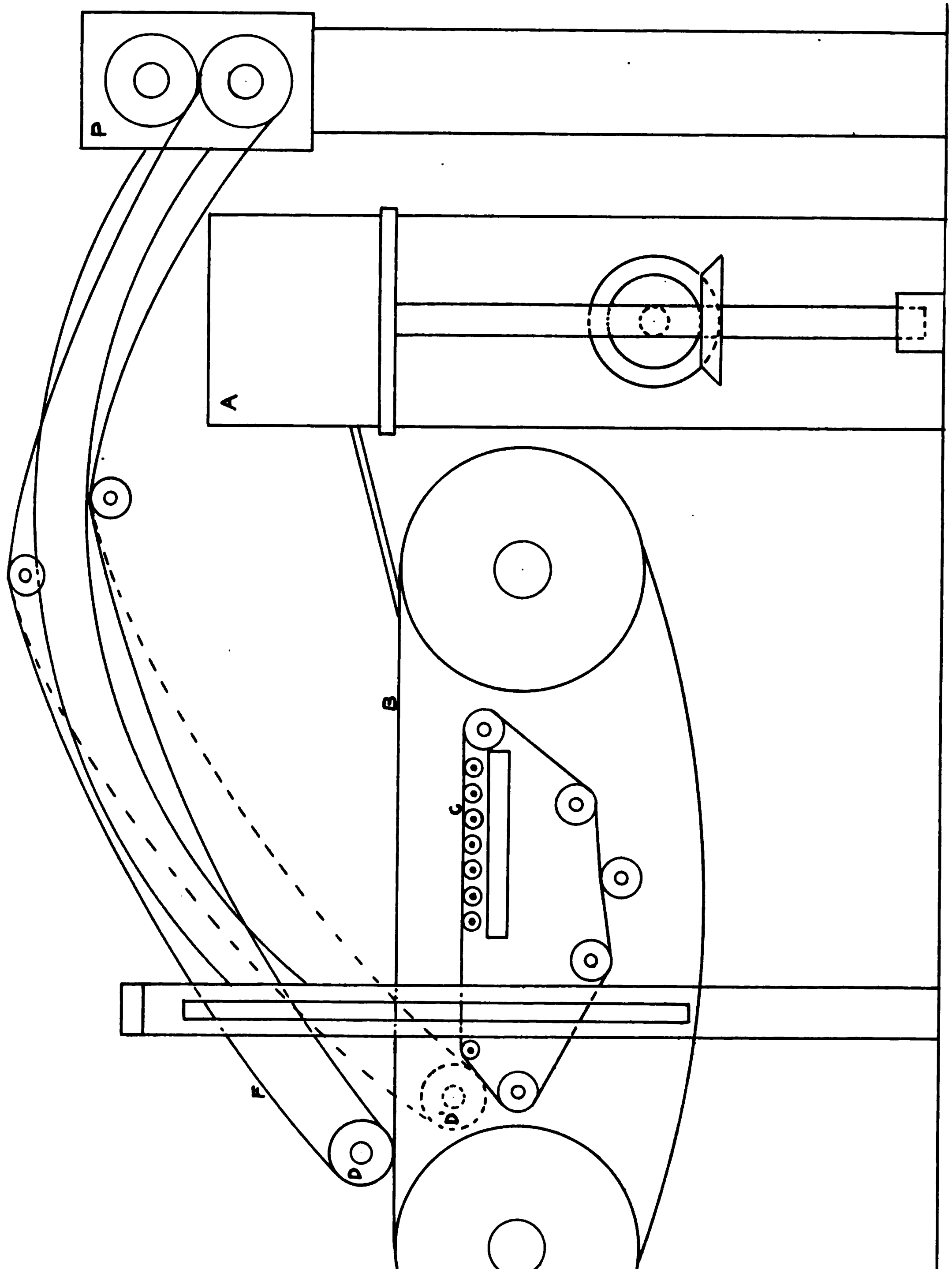
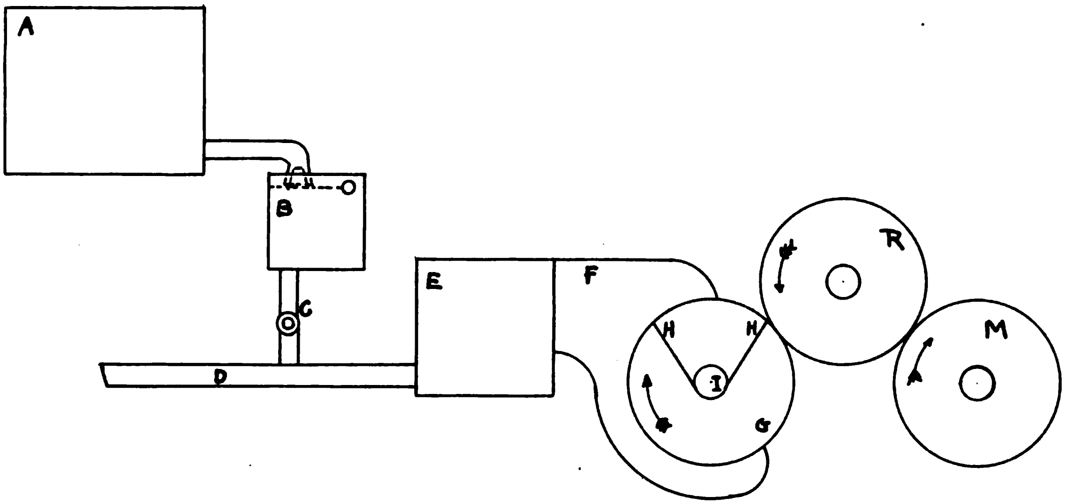


PLATE IV.



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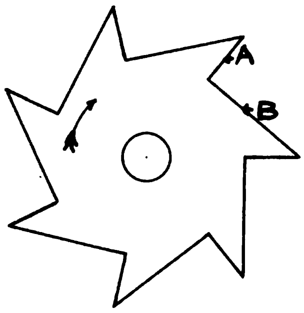

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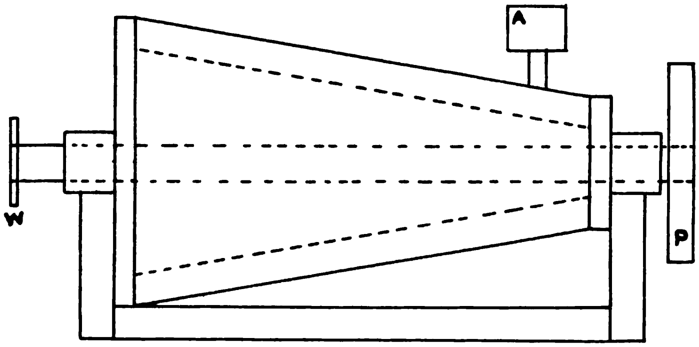

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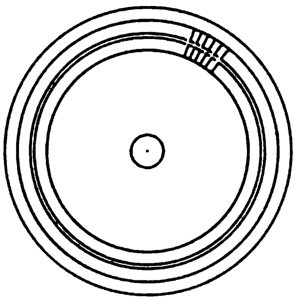

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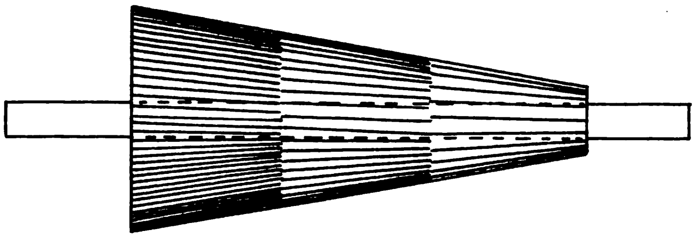
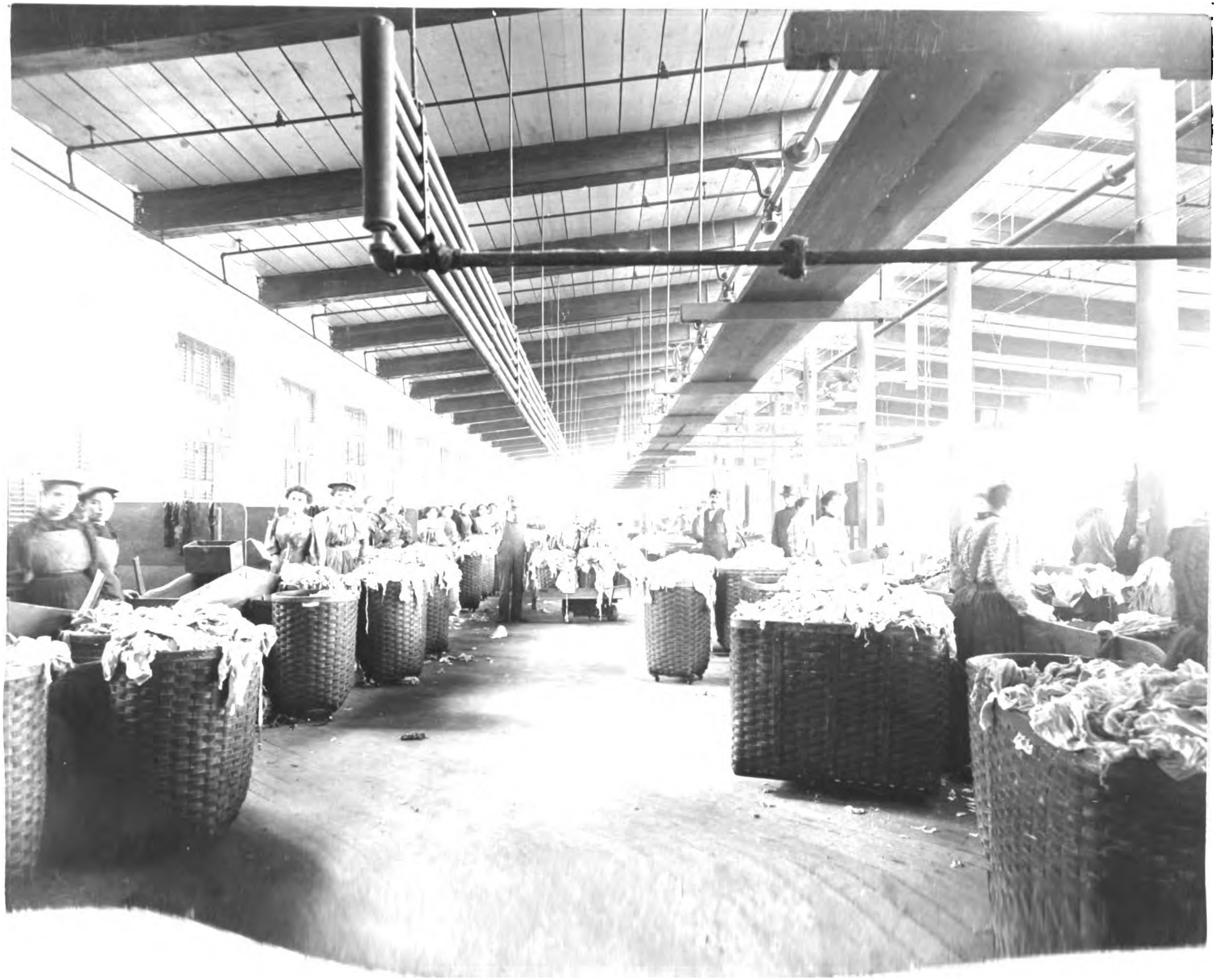


FIG. 4.

PLATE V.

PLATE VI-



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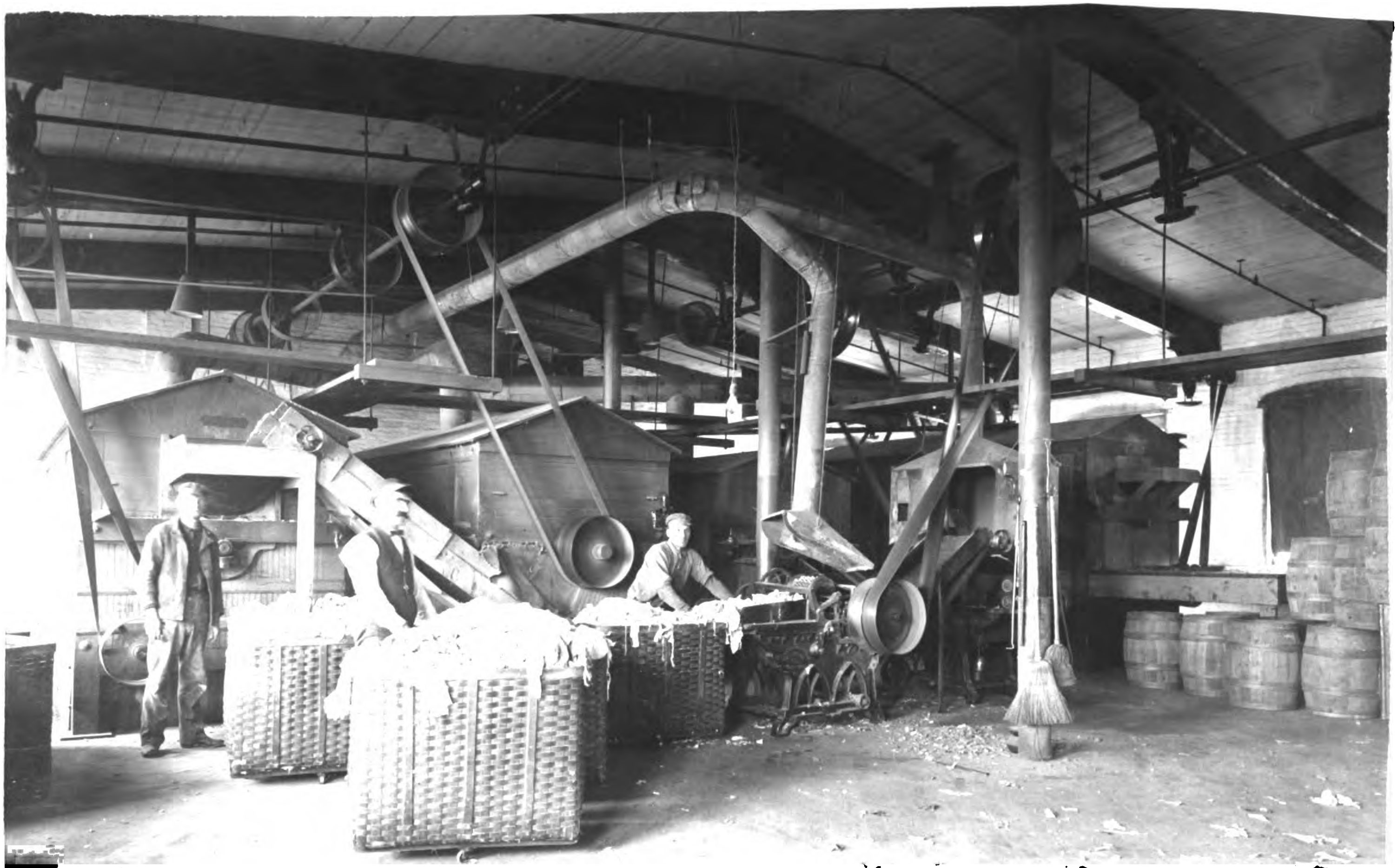


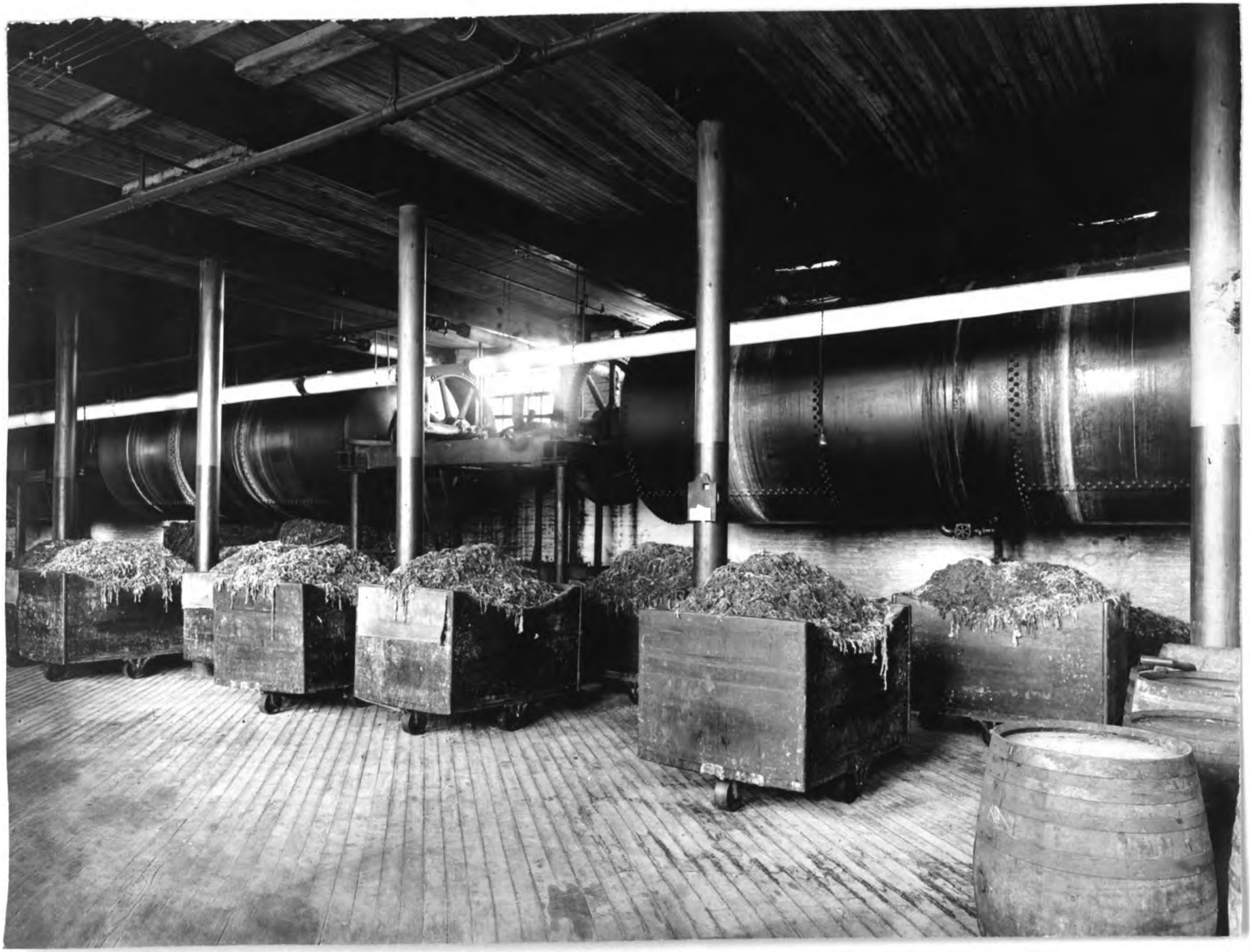


PLATE IX.

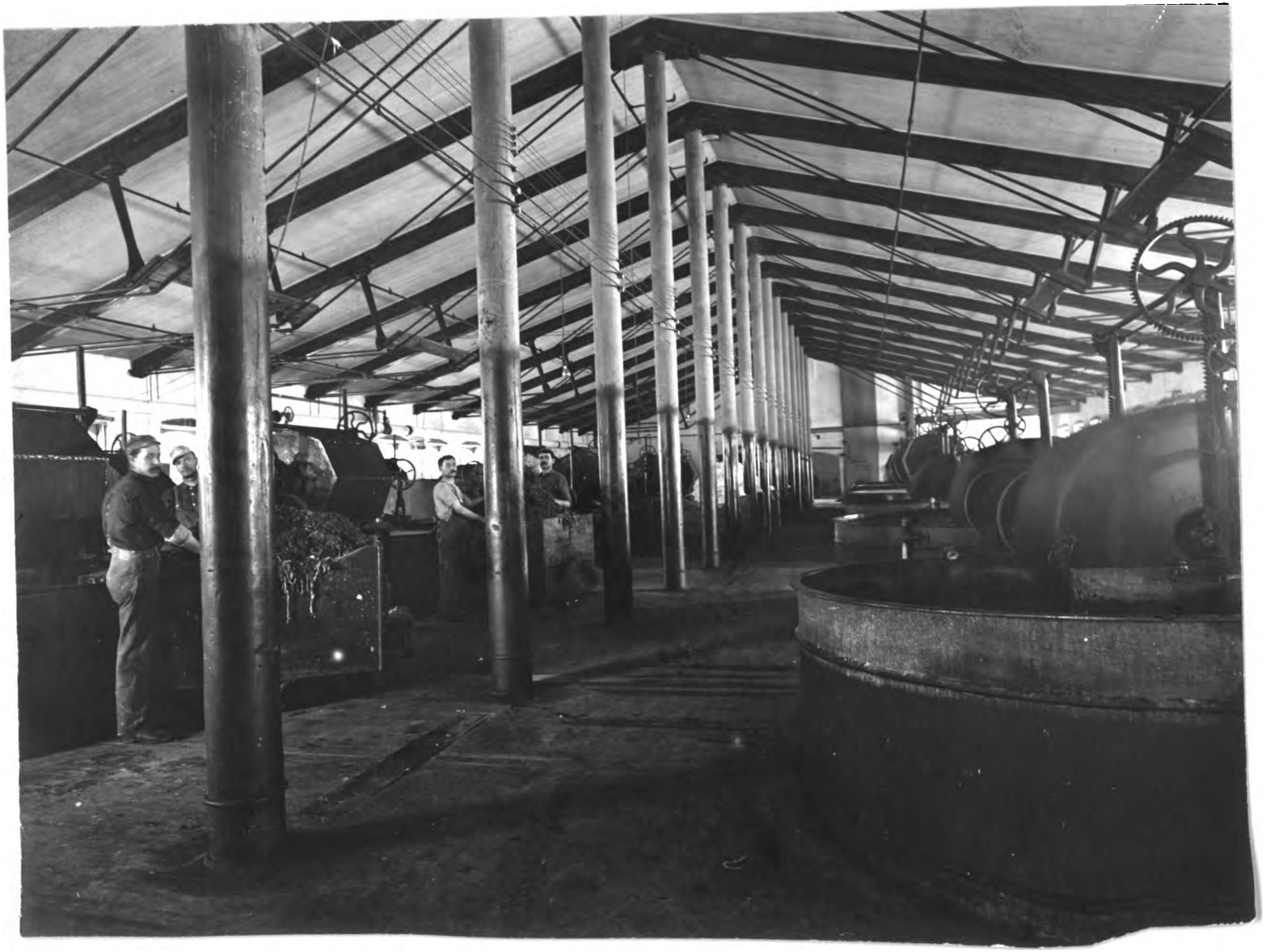


PLATE X.

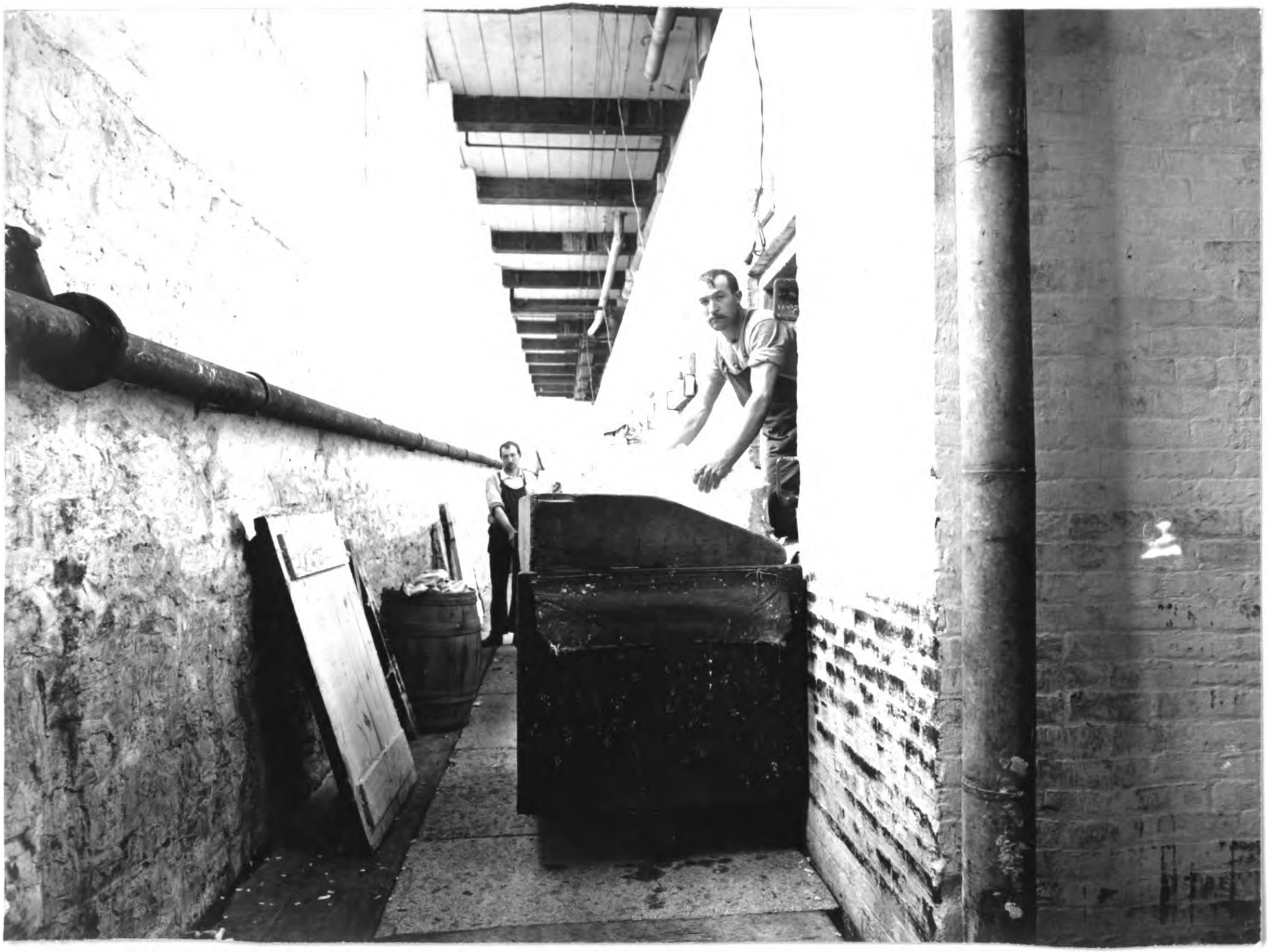
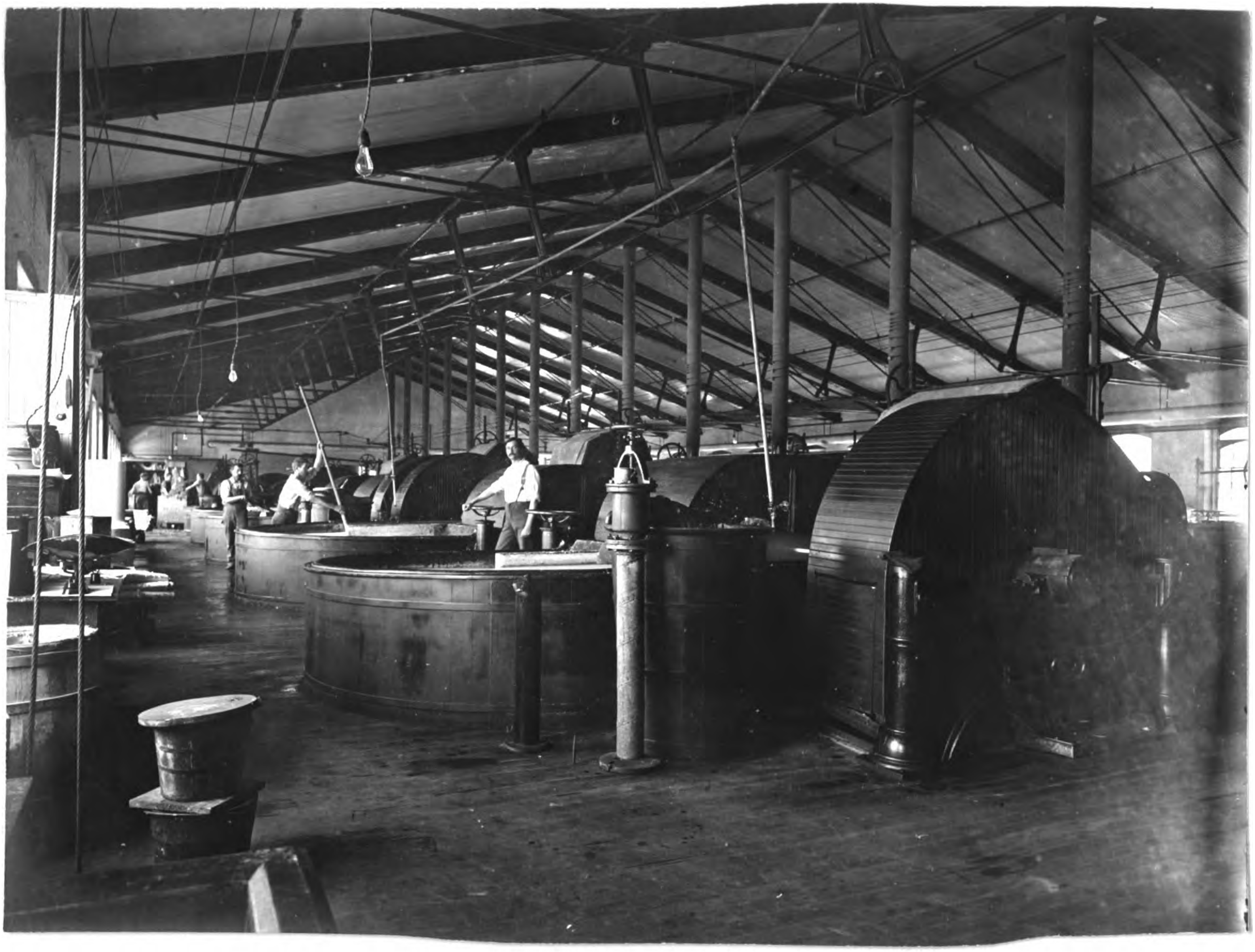
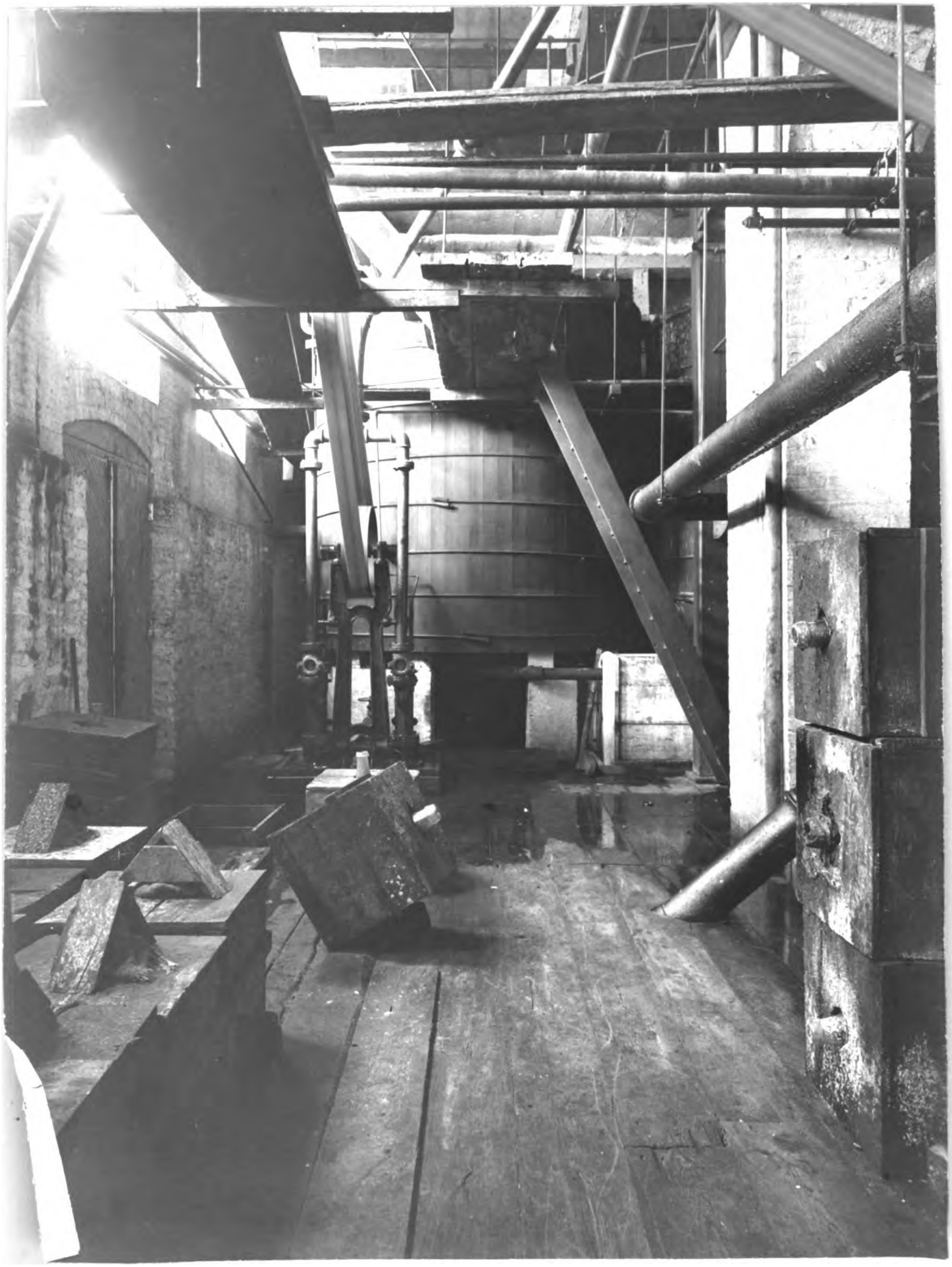
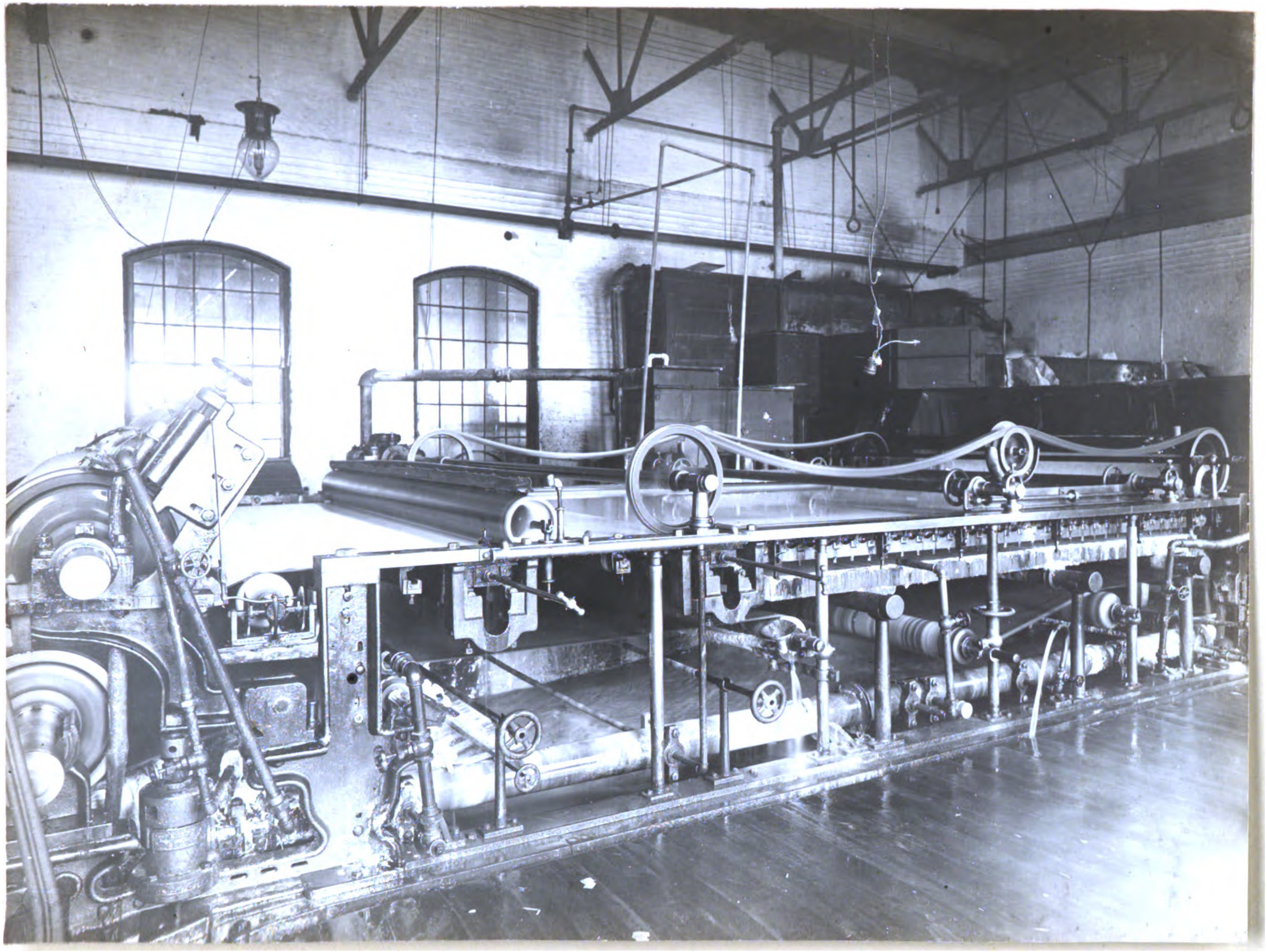


PLATE XI.







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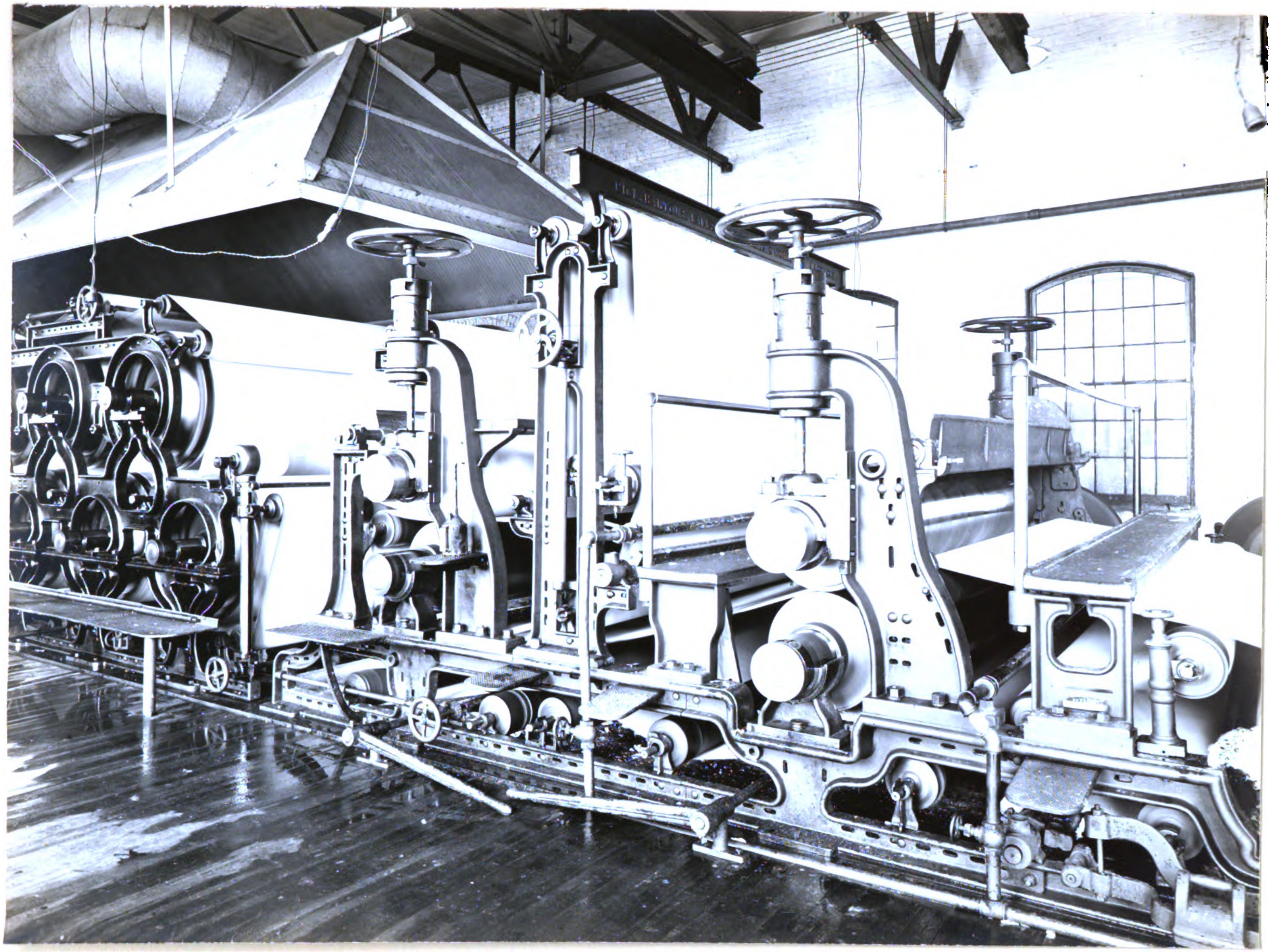

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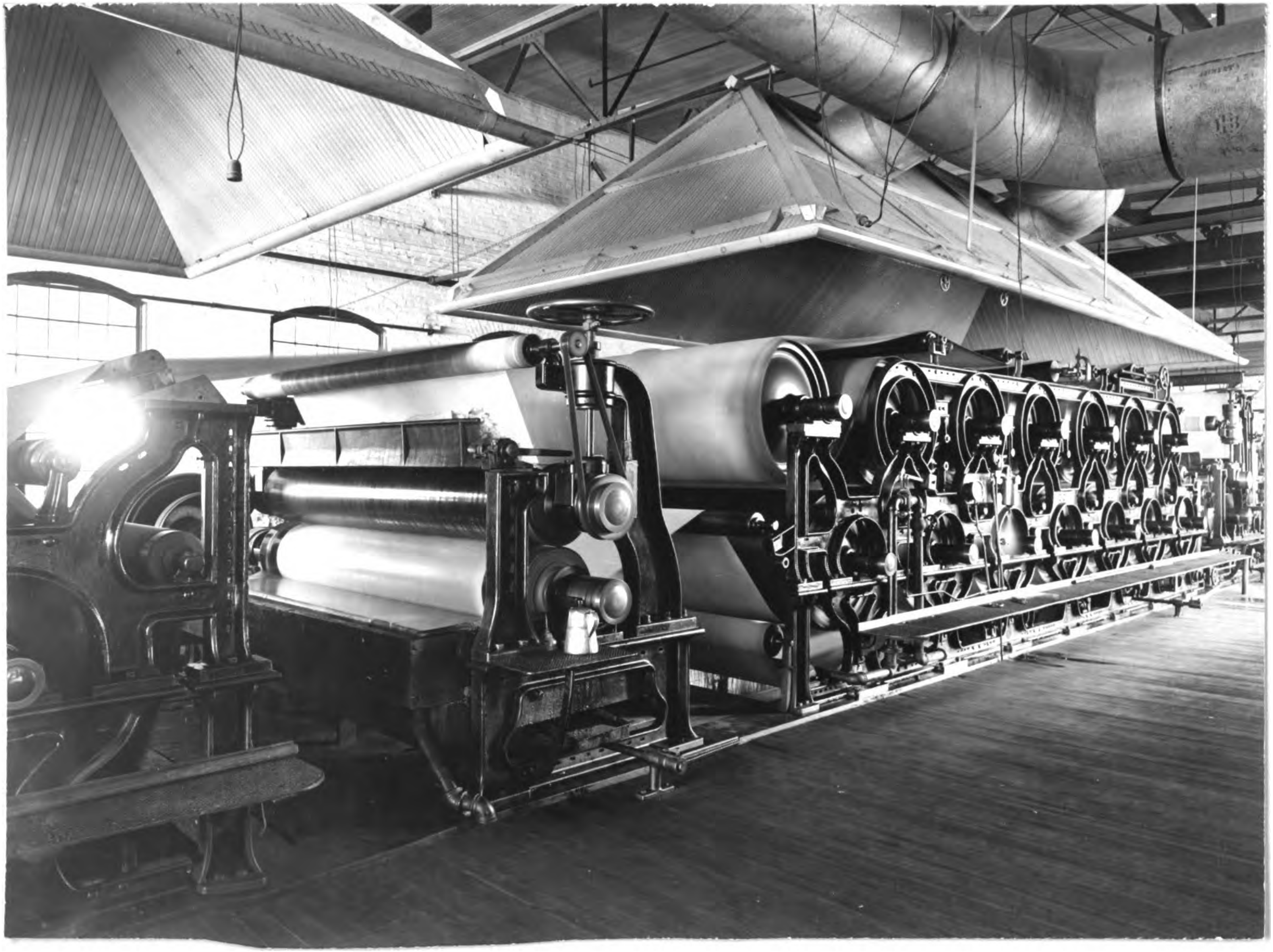

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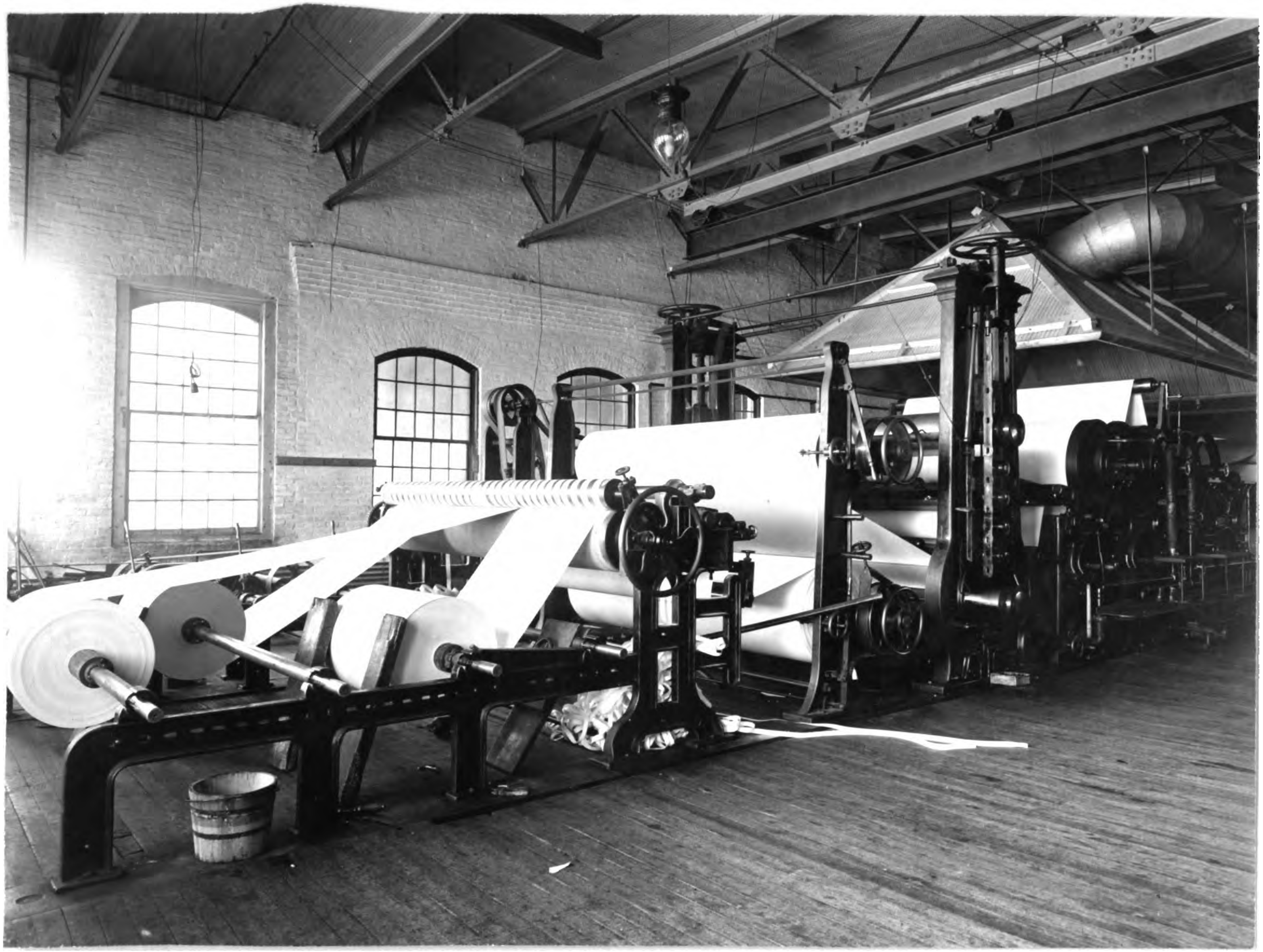

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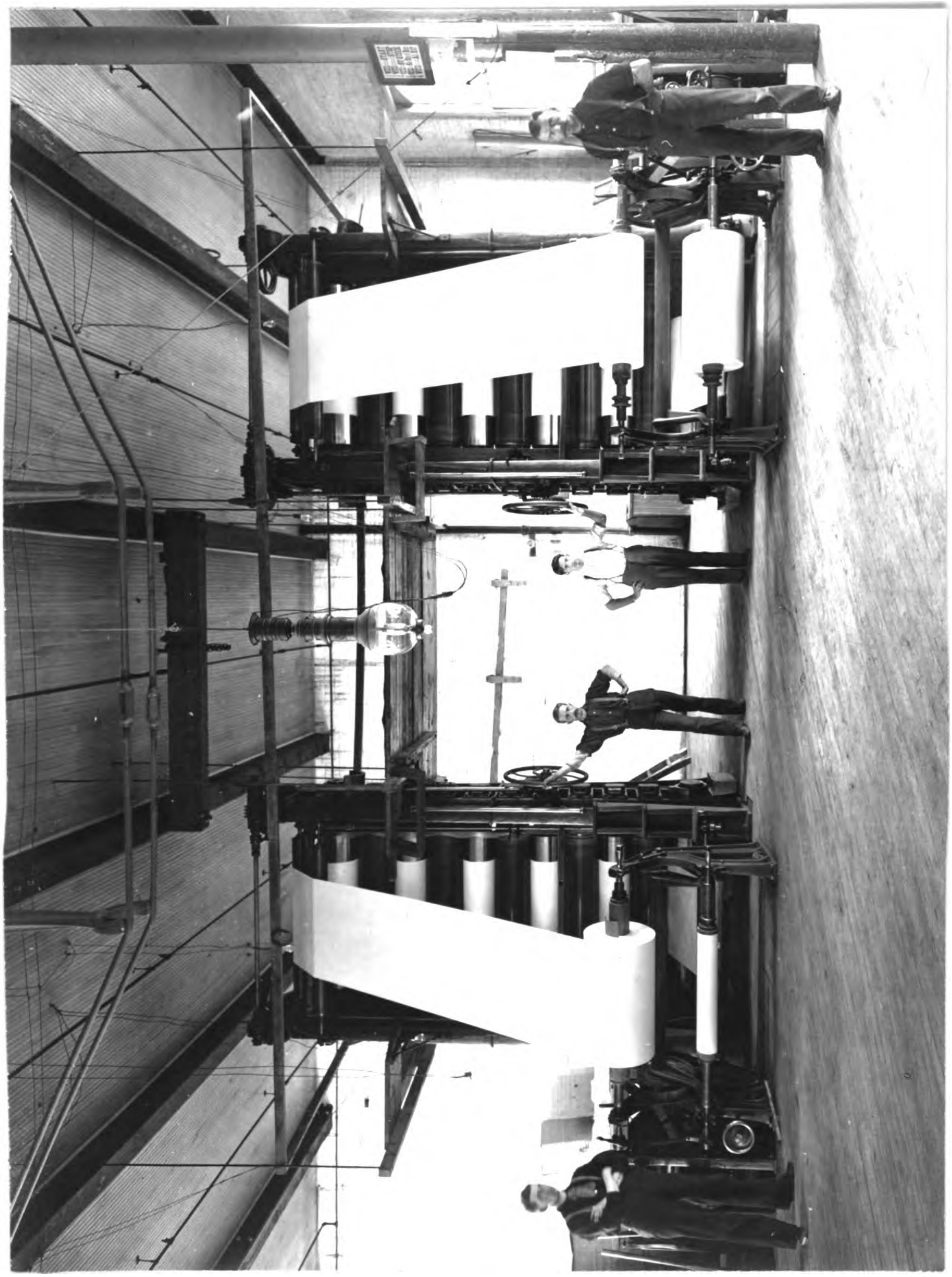

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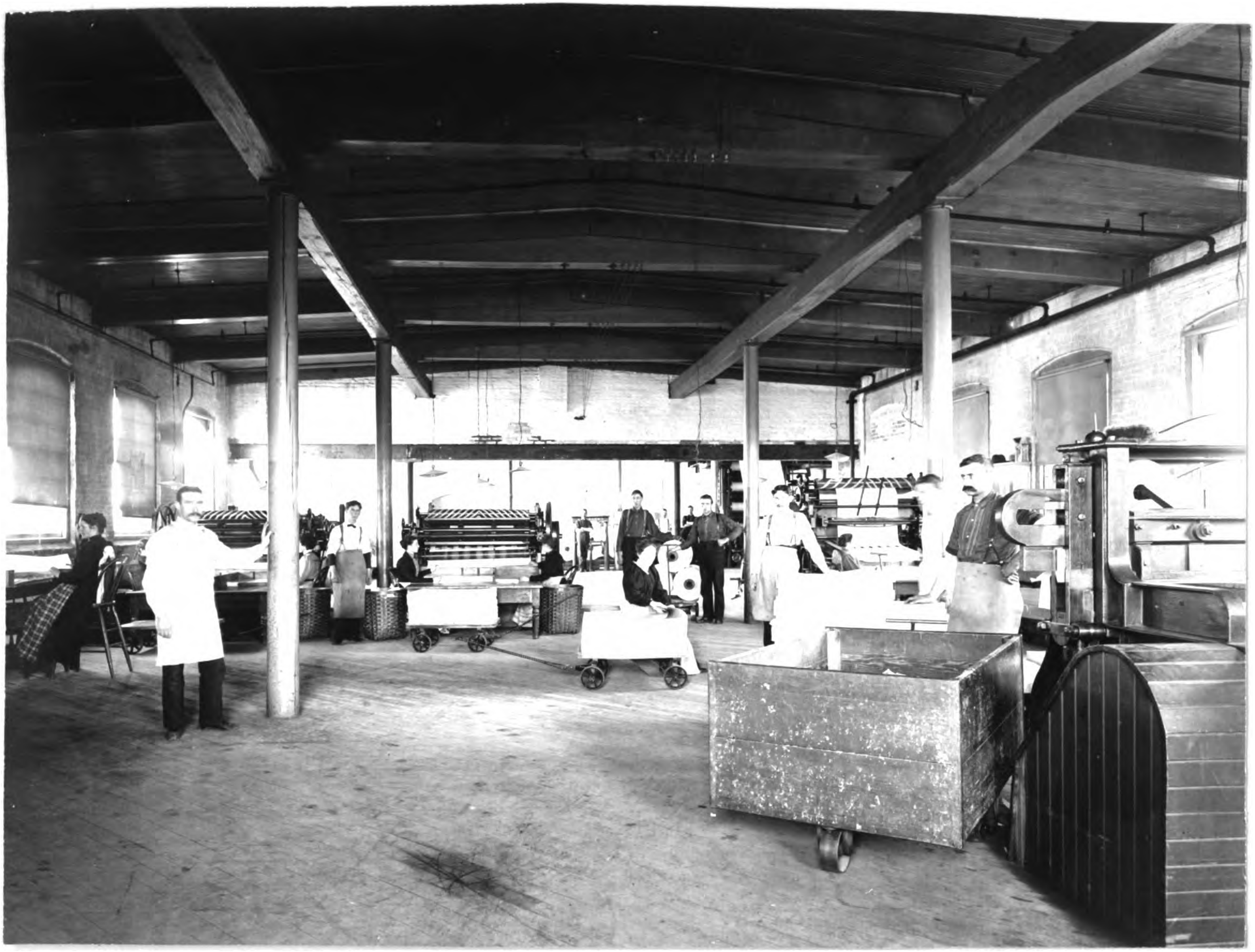

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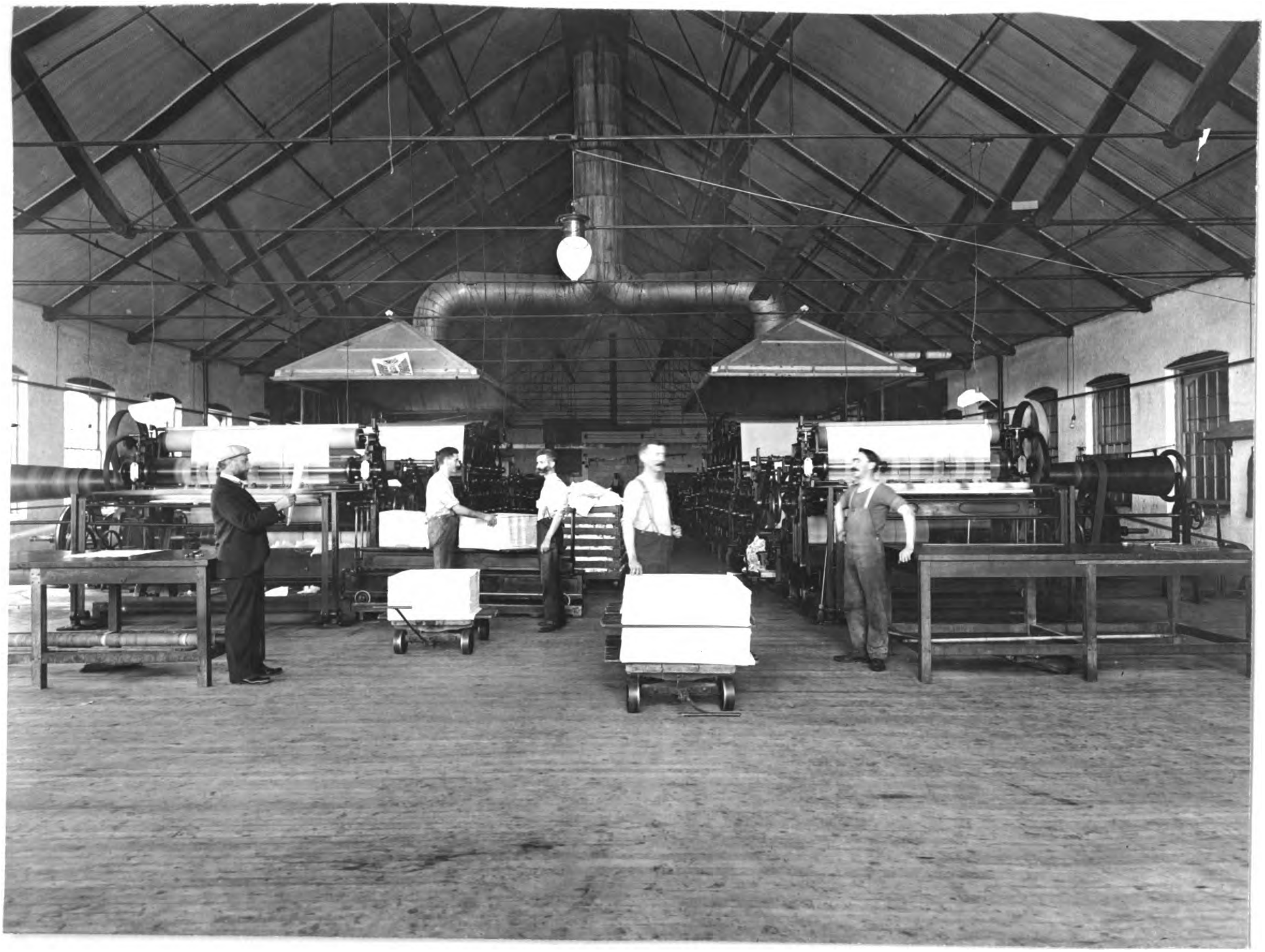


PLATE XX.

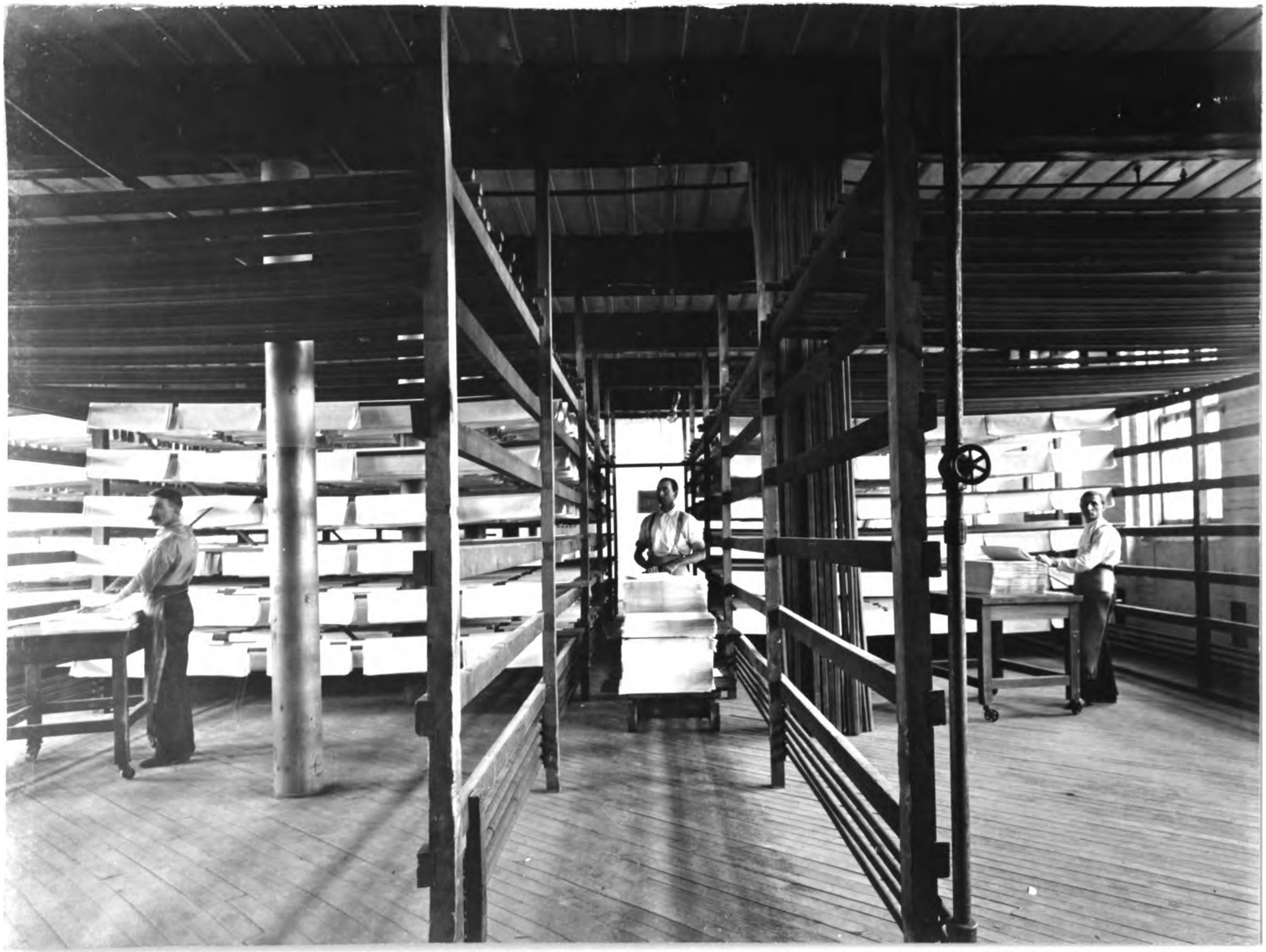


PLATE XXI.

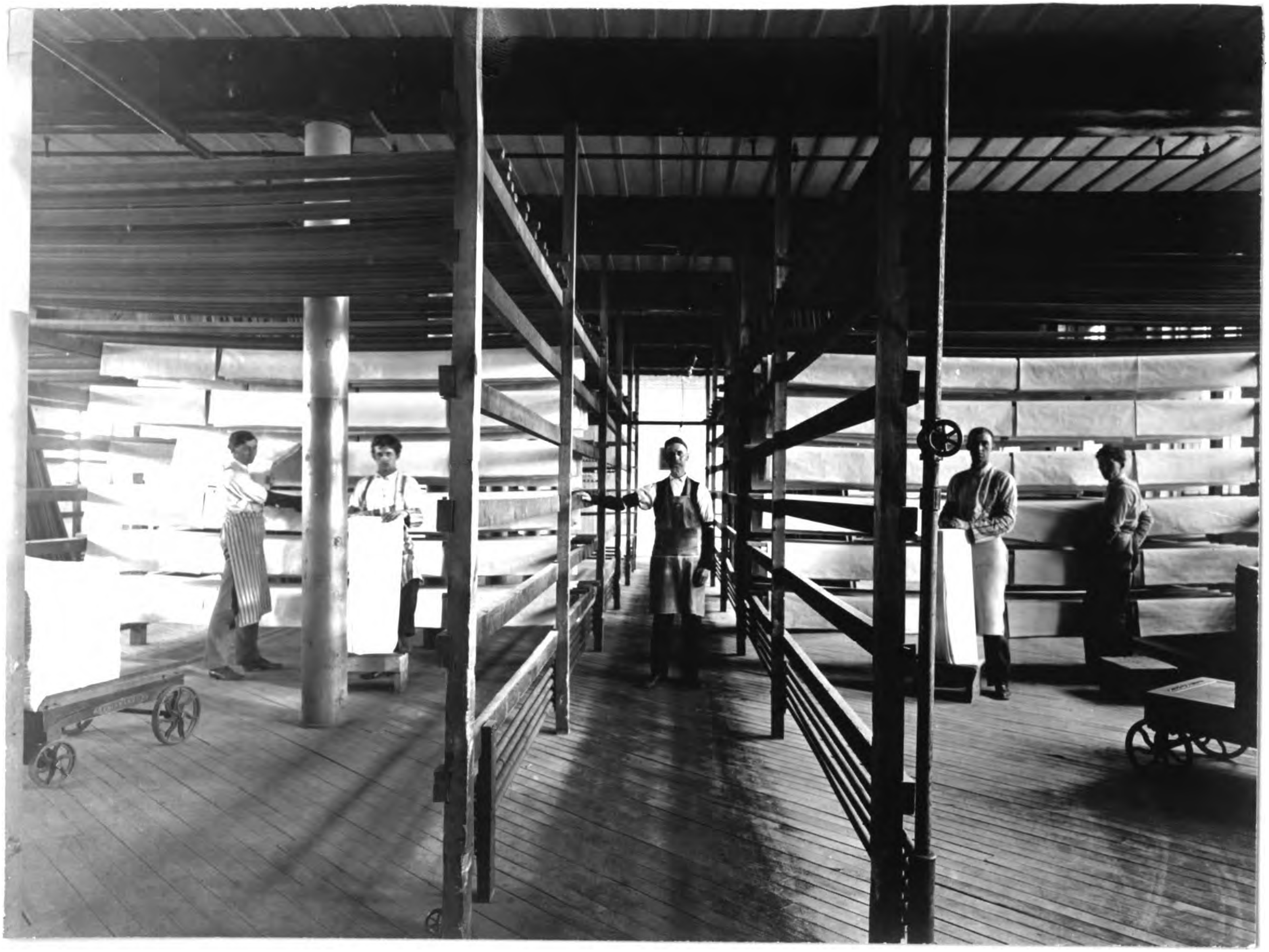


PLATE XXII.

PLATE XXIII.

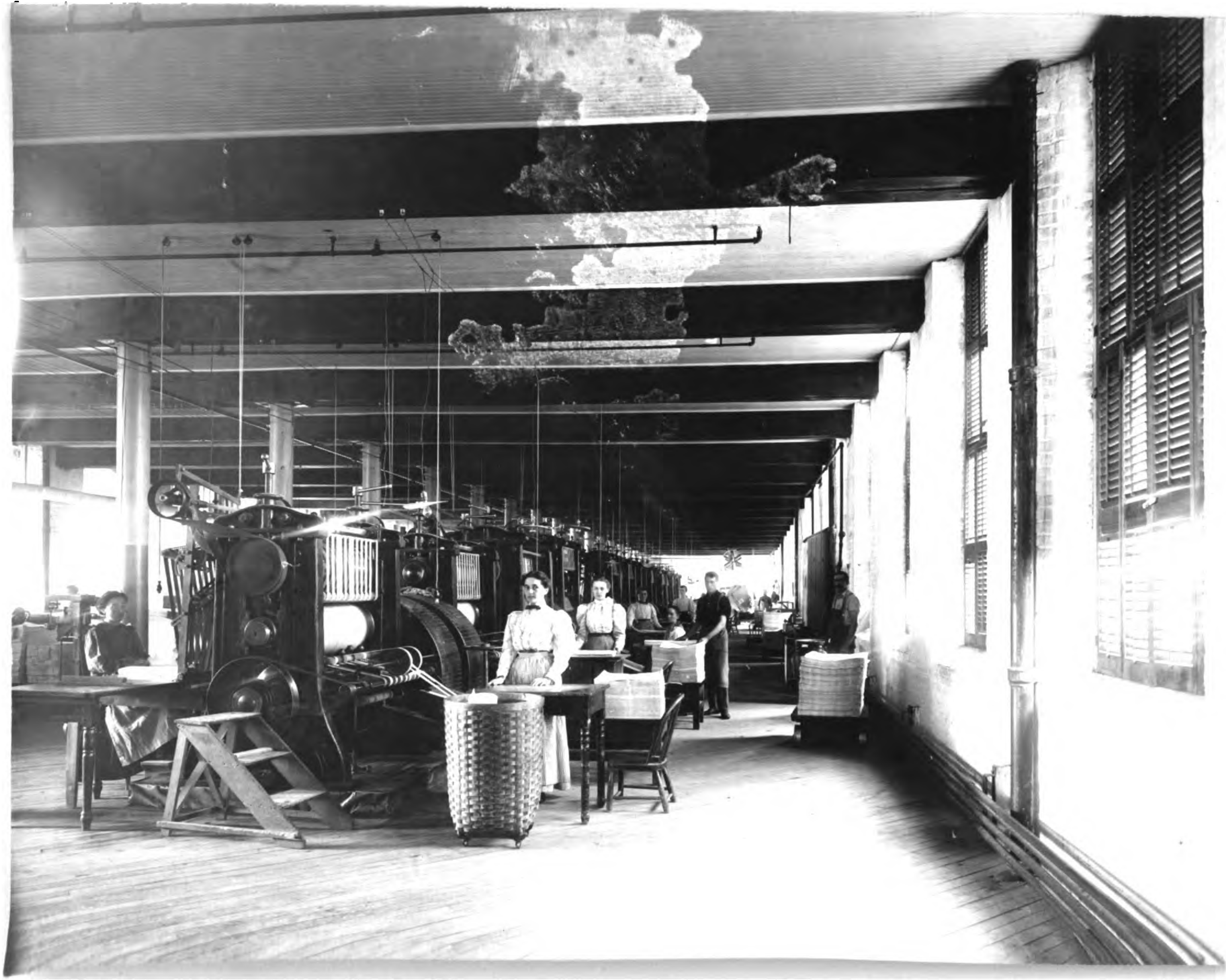


PLATE XXIV.

PLATE XXV.

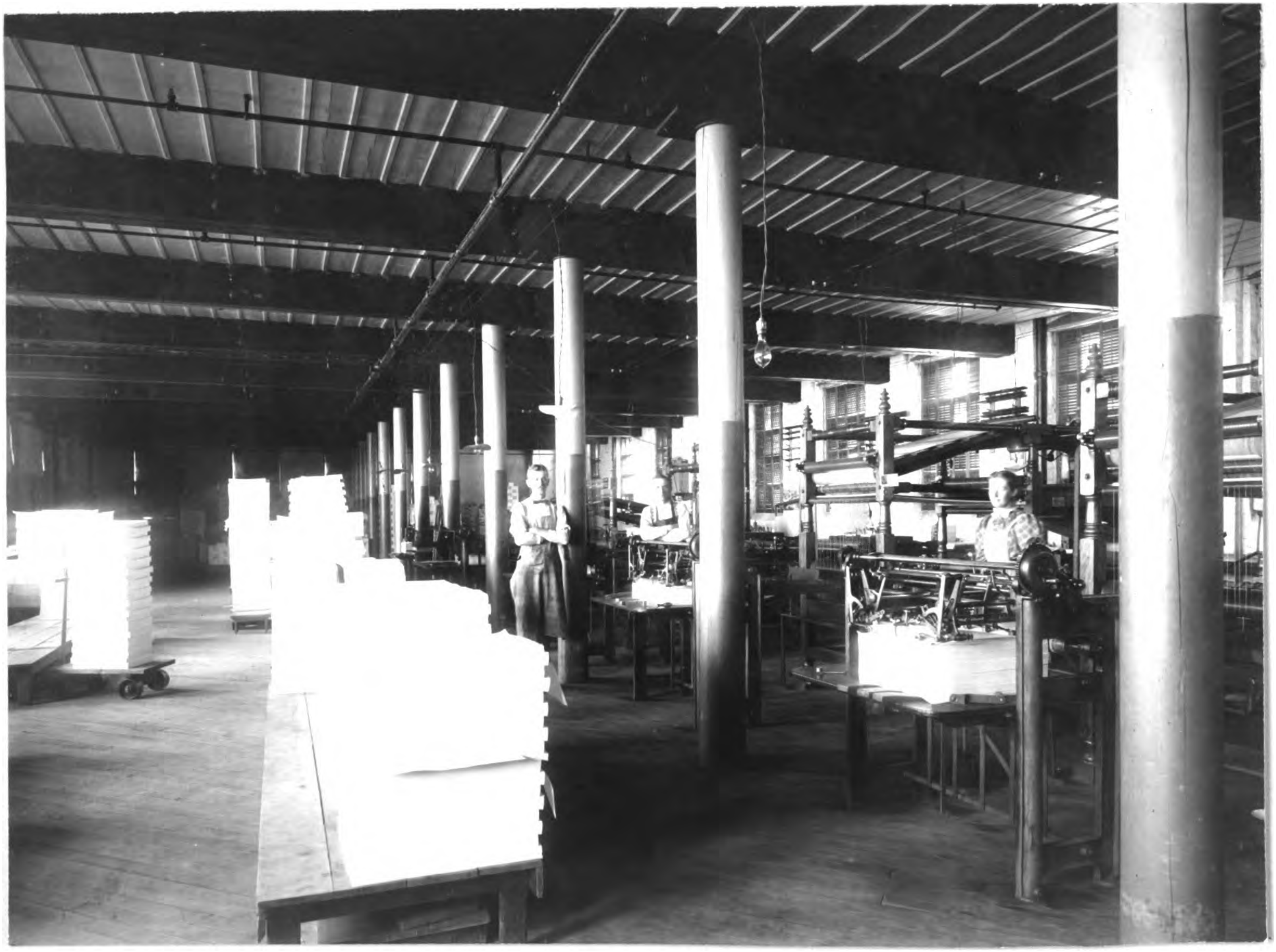


PLATE XXVI.

TABLE I.-UNITED STATES.

YEAR	NO. MILLS	CAPITAL	MATERIAL	AMT. PRODUCT	VALUE PRODUCT	AMT. RAGS	VALUE RAGS	AMT. WRITINGS	VALUE WRITINGS
1770	40	—	—	—	—	—	—	—	—
1810	179[1]	—	—	428¼ Tons	\$1,618,718	—	—	—	—
1820	108	—	—	—	\$3,000,000	—	—	—	—
1830	-	—	—	—	—	—	—	—	—
1840	426	\$4,745,239	—	—	\$5,641,499	—	—	—	—
1850	443	\$7,260,864	\$5,553,929	—	\$10,187,177	—	—	—	—
1860	555	\$11,052,683	\$11,602,266	126,889 Tons	\$21,216,802	—	—	11,134 Tons	—
1870	46[2]	\$6,314,000	—	—	—	—	\$6,009,000	—	\$9,363,384
1880	692[3]	\$46,241,202	\$33,951,297	—	\$55,109,914	187,917 Tons	—	32,937 Tons	—
1890	649[3]	\$89,829,548	\$44,228,480	934,511 Tons	\$69,294,306	246,892 Tons	\$8,407,060	64,573 Tons	\$11,939,576
1900	763[3]	\$167,507,173	\$70,530,236	2,167,593 Tons	\$107,869,046	234,514 Tons	\$6,595,427	112,707 Tons	\$15,895,974

[1] EXCLUSIVE OF MASS.

[2] NO. WRITING MILLS.

[3] NO. ESTABLISHMENTS.

TABLE II. MASSACHUSETTS.

YEAR	NO. MILLS	CAPITAL	MATERIAL	AMT. PRODUCT	VALUE PRODUCT	AMT. RAGS	VALUE RAGS	AMT. WRITINGS	VALUE WRITINGS
1796	20	—	—	70,000 Rms	—	—	—	—	—
1810	—	—	—	95,129 Rms 22,500 Rolls	$290,951	—	—	—	—
1820	9	—	—	—	—	—	—	—	—
1840	82	—	—	—	$1,659,930	—	—	—	—
1845	—	—	—	—	$1,750,273	—	—	—	—
1855	121	—	—	17959 Tons	$4,141,847	—	—	—	—
1860	99	—	—	—	$6,170,127	—	—	7,799 Tons	—
1870	30[1]	$4,387,828	$3,638,470	—	—	—	—	—	$6,025,595
1880	96[2]	—	—	—	$15,188,196	—	—	24,746 Tons	—
1890	85[2]	$22,467,036	$12,210,458	157,671 Tons	$20,491,527	116,068 Tons	$4,078,517	45,157 Tons	$8,911,723
1900	93[2]	$26,692,922	$11,918,802	224,509 Tons	$21,549,232	86,715 Tons	$3,306,599	68,055 Tons	$11,298,628

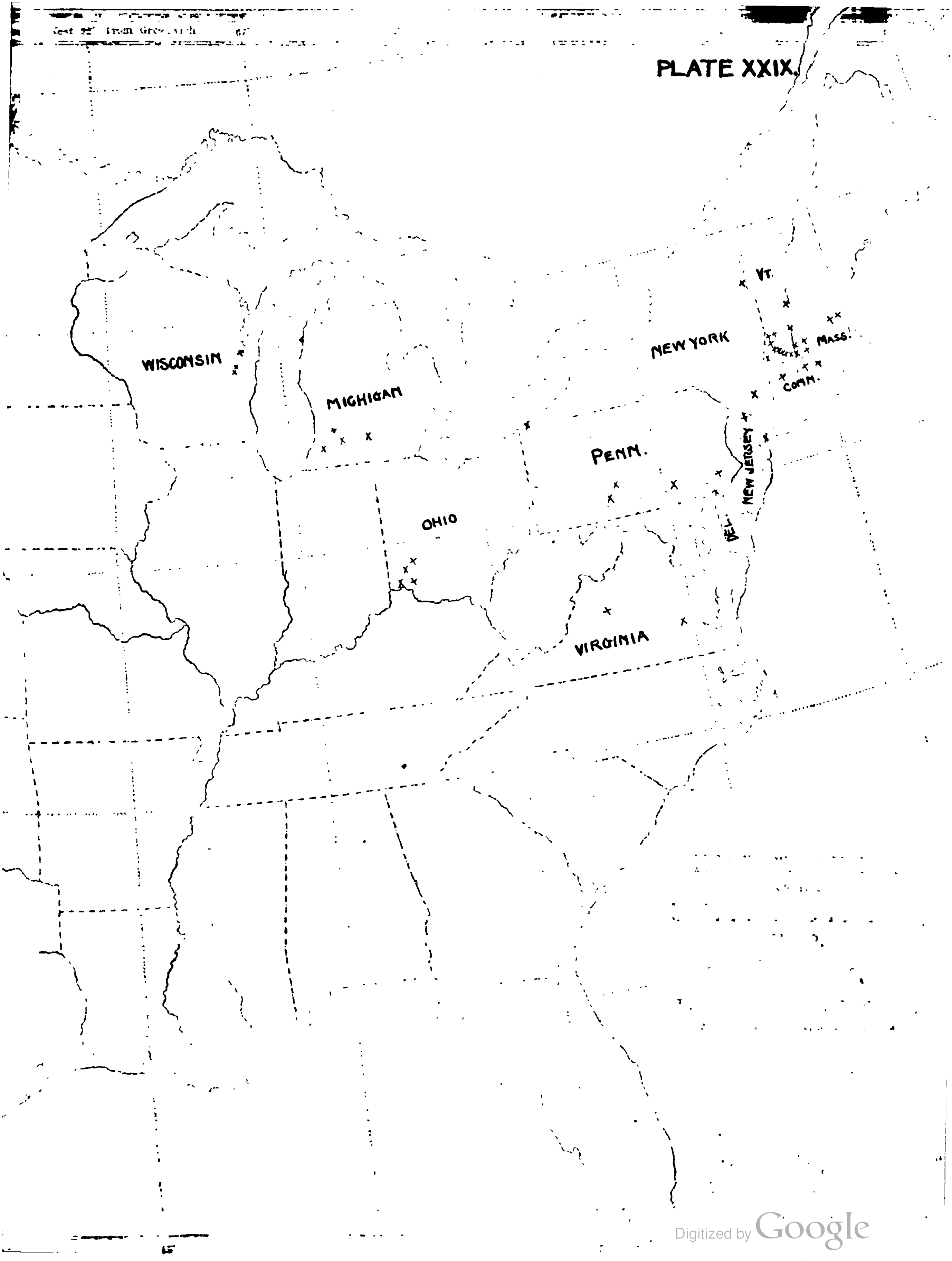
[1] NO. WRITING MILLS.

[2] NO. ESTABLISHMENTS.

TABLE III. WISCONSIN.

YEAR	NO. MILLS	CAPITAL	MATERIAL	AMT. PRODUCT	VALUE PRODUCT	AMT. RAGS	VALUE RAGS	AMT. WRITINGS	VALUE WRITINGS
1850	—	—	—	—	$15,000	—	—	—	—
1860	5	—	—	862 Tons	$193,000	—	—	—	—
1870	6	$445,000	$225,197	—	$373,200	—	—	—	—
1880	—	—	—	—	—	—	—	—	—
1890	27	$5,360,624	$2,588,863	54,323 Tons	$4,015,607	23,134 Tons	$757,167	2,353 Tons	$369,151
1900	47	$16,580,140	$6,712,749	186,731 Tons	$9,037,461	29,049 Tons	$717,409	13,991 Tons	$1,489,199

PLATE XXIX.


from Greenwich
WISCONSIN
MICHIGAN
OHIO
NEW YORK
VT.
MASS.
CONN.
PENN.
NEW JERSEY
DEL.
VIRGINIA
85

HICKORY BOND
PINK.

HICKORY BOND
BLUE.

HICKORY BOND
GREEN.

HICKORY BOND
P.RIMROSE.

HICKORY BOND.
CORN.

HICKORY BOND
GOLDEN ROD.

NO.1. FINES
CREAM.

NO.1. FINES.
HELIOTROPE.

NO.1. FINES
AZURE.

NO.I. FINES
MARGUERITE.

NO.1. FINES
SHELL ROSE.

NO. I. FINES
OPALINE.

OLYMPIA BOND
WHITE.

OLYMPIA BOND
PRIMROSE.

OLYMPIA BOND
PINK.

OLYMPIA BOND
BLUE.

OLYMPIA BOND
CANARY.

OLYMPIA BOND
GOLDEN-ROD.

VIGILANT BOND
WHITE.

VIGILANT BOND
PINK.

VIGILANT BOND
BLUE.

VIGILANT BOND
BUFF.

NO.3 ENGINE SIZED
GOLDEN-ROD.

Accepted May ..[illegible]...., 1903

Approved, May .7...., 1903

By ....

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